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PRESIDENT'S MESSAGE - LOUISIANA

Harold S. Birkett  
F. C. Schaffer & Associates, Inc.  
Baton Rouge, Louisiana

The 1986 crop in Louisiana was a better crop than in the previous several years. There was 9.5 percent more acreage than in 1985, and this was the largest crop since 1978.

The outlook for the 1987 Louisiana crop is good. The mild (although rainy) winter did not affect the crop, and the cane population is good. In April, both record low and high temperatures were recorded. The effect of the weather on the crop has not been fully determined, but we are expecting a good crop.

The Administration has proposed lowering the loan level from 18 cents to 12 cents per pound over a period of several years. Under this proposal, there would be a system of payments to growers as the loan level is reduced. The Administration's plan, however, is not expected to be implemented. The current Farm Bill that includes sugar extends through the 1990 crop. As sugar producers and processors, we need to keep abreast of political developments and keep our congressmen and legislators informed of our interests so that they can continue their efforts to aid the industry.

Over the last 15 years, the number of factories in Louisiana has declined from 43 to 21. The tons of cane processed per crop has shown little decline, resulting in a steady increase in factory capacities. In 1971, the average factory's grinding rate was 120 short tons of cane per hour. The current state average grinding rate is now 220 tons of cane per hour.

Cane quality has improved due to work done in plant breeding. Syrup purities have shown a corresponding rise from 80 to 85. As syrup purities have increased, so has the pol of the sugar produced. The average sugar pol has increased by a full pol unit over the last 15 years to the current average sugar pol of 98.3.

These improvements in sugar yield and juice quality reflect the research efforts of many. The USDA's agronomists work on germplasm enhancement and breeding have resulted in numerous successful commercial varieties. The work of USDA and LSU agronomists, entomologists, and pathologists working in cooperation has resulted in improved cane varieties and in better methods for the control of disease, insects, and weeds. Improvements in cultural and fertilization practices have also played a role.

The role played by the LSU Extension Service and the American Sugar Cane League, with the help of county agents, in transferring the latest developments to the growers results in the rapid deployment of the latest technology.

The Farm Bureau has assisted the growers through its sugar advisory and special research committees, as well as with its lobbying and funding efforts.

The cane varieties being developed will concentrate on increased tonnage and higher population, along with improved disease resistance and greater cold tolerance. Further increases in sucrose content will probably be less dramatic than has been the case in the last 15 years.

The use of the two-row harvester and chain piler have both contributed to cleaner cane and the improvement of sugar yields per ton of cane. Local universities have provided training directly related to the needs of the sugar industry.

The Audubon Sugar Institute has provided assistance to factories in order to improve many facets of factory operations. A program is currently underway to investigate the causes, effects and cures for dextran. Work is also being carried out in the search for a quick, simple and accurate method for the determination of dextran in juices.

In the continuing effort to reduce the cost of sugar, improvements in both field and factory operations will be necessary. One way to save labor is through automation. This is an area that will expand in the near future. Improved automatic controls are increasingly being applied at boiler and centrifugal, stations and

continued automation is expected at the evaporator and sugar boiling stations. The difficulty and cost of obtaining qualified personnel for seasonal operations will continue to be the driving force for the increased use of automatic controls.

The extremely wet 1986 season, and the hurricane and rains of the 1985 crop, have made it painfully clear that we need improvements in harvesters and loaders that will deliver clean cane under muddy field conditions. The use of chain pilers was found to be an improvement this year. Undoubtedly, the use of chain pilers and other improvements in loaders will continue to be made.

Over the last 15 years, gas consumption has been reduced from 1.2 million cubic feet per ton of cane to 0.2. Although this is a great improvement, continued efforts to reduce gas consumption to zero, while generating all of the factory's electricity, is an achievable goal that should be addressed. Further decreases in gas consumption will require a continuation of the efforts already implemented, including cleaner delivered cane, improved cane washing, the use of higher pressure live steam, the use of more efficient steam production by the use of air preheaters and close monitoring of excess air, modifications to the evaporator scheme to reduce the exhaust steam requirements of the factory, and the installation of adequate bagasse storage facilities.

Another fruitful area for factory improvements is in milling operations. Substantial improvements in mill extraction can be achieved with higher levels of imbibition and improved mill feeding provisions. In Louisiana, the milling loss in bagasse represents the greatest manufacturing loss. Improvements in milling are clearly an economic opportunity worth pursuing. Improvements in milling are expected to come from improved mill feeding, higher levels of imbibition and closer monitoring of mills to ensure that each mill in the tandem is working well.

The industry's commitment to continued research is evidenced by the increase in dues passed last year that will be dedicated to research. A further increase has been approved for the 1987 crop. These research funds will help to offset the decreased funding resulting from the current economic squeeze.

It is technological improvements that will keep our industry competitive. It is the goal of the Society to help the mainland sugarcane industry. The speeches and the informal discussions that make these meetings enjoyable are also the source of ideas that will improve our industry. We hope that all attendees will enjoy this 17th joint meeting of the ASSCT and that all of you will leave with new ideas and renewed enthusiasm.



PRESIDENT'S MESSAGE - FLORIDA DIVISION

Wayne Beardsley  
United States Sugar Corporation  
Clewiston, Florida

On behalf of the Florida Division of the American Society of Sugar Cane Technologists, I would like to thank the Louisiana Division for hosting the 17th Annual Joint Conference in Fort Walton Beach, Florida.

This year, we have Mother Nature to thank for our bountiful crop. Despite a slow start due to unseasonably warm weather, which slowed down both field and processing operations, we had an exceptionally good season. This is just the second time in the last 12 years that we did not experience freeze damage to our sugarcane crop. During the 173 days of the 1986/87 harvesting campaign, Florida's 130 sugarcane growers harvested over 13.7 million short tons of sugarcane from 384,000 acres yielding 1,476 million tons of sugar, raw value. Mechanical harvesting continues to play an increasingly important role in our cane delivery operations, with some 4.3 million tons being harvested by this method. Our average yield was at 10.57 percent 96° sugar. Florida has remained the number one sugar-producing state in the nation, generating 22 percent of the sugar produced and 18 percent of the sugar consumed.

In Florida, we have been busy on the environmental and legislative fronts. Led by the Florida Sugar Cane League's Environmental Quality Committee, the industry has played a key role in developing a course for preserving water quality and quantity in Lake Okeechobee--the industry's major water resource. Members and consultants in the industry were active participants on the Lake Okeechobee Technical Advisory Committee which has made recommendations to state and federal agencies on what course of action to take in controlling the eutrophication process of Lake Okeechobee, while still addressing water supply needs.

In addition to providing irrigation and drainage needs for sugarcane, the lake supplies water for the vegetable, sod, cattle and citrus industries. It's also used as a direct source of drinking water for over 40,000 people who live in communities around the lake, and as an indirect source for more than 4 million people who reside on Florida's east coast.

We support a program that gives equal consideration to water quality and supply. It would be just as devastating to experience a killing drought because of short-sightedness on water supply, as it would be to have excess nutrients going into the lake. At this point in time, we are faced with decisions which will affect the economy of surrounding areas regarding Lake Okeechobee and conflicting water needs. We are ready to work with state and federal regulators and others who are interested in the "Big Lake" to achieve a balanced plan of action to protect both water quality and quantity.

The industry has also met the challenges in open burning regulation and mill emission testing. The Florida industry has entered into a cooperative agreement with the state of Florida whereby the Florida Sugar Cane League administers pre-harvest burn permits, saving the state hundreds of thousands of dollars in regulatory expenses. The League operates 21 ambient air monitoring stations throughout the Everglades agricultural area to assure that state and federal air standards are observed.

In legislative affairs, we won the battle in getting the 1985 Farm Bill passed, but the war is definitely not over. We continue to have stiff opposition from the Administration and industrial sugar users on the current sugar program. Sugar has been and will continue to be a political football in Washington. Lawmakers continue to try to use the domestic sugar program as a foreign policy tool rather than as a farm program.

Every sugar-exporting nation practices some sort of market intervention to protect its respective domestic sugar markets. According to a recent study, all major exporters guarantee a producer price minimum and most control exports and the amount available for domestic consumption. Therefore, there is no such thing as a world or free market, only a dumping ground for the excess sugar that's not traded under preferred contracts or used for domestic consumption in the country of origin. We are fortunate that we have the technology and ability to compete

with other sugar-producing countries in spite of heavy subsidization from their governments. It is by using research such as that being presented at the ASSCT Joint Meeting which keeps our industry viable.

Despite our advanced technology, however, our industry is constantly being attacked by large industrial sugar users who have mounted a campaign against the sugar program. They use the "consumer will save" myth as their basis to change the program. Actually, lowering the loan rate from 18 cents to 12 cents will only add to the pocketbooks of industrial food users. For example, a one-cent reduction in the price of sweetener amounts to a \$20 million increase in profits for the largest soft drink company. This amounts to an over \$1 billion windfall for the "Big 9" sugar users. It is highly questionable that this benefit will be passed on to final consumers. The value of sugar in a 35 cent candy bar is 2 cents. If sugar were free, the price of the candy bar would probably remain the same.

The 1985 Farm Bill has a no-cost provision written into it that protects American taxpayers from having to subsidize our industry. By setting the import quota at the correct level, the current program controls domestic prices in order to prevent any forfeitures on possible sugar loans. As we look ahead, statesmanship dictates that we, the whole domestic industry, move in a cohesive manner to take a hard look at our production and domestic consumption patterns.

Currently, we are fortunate to have a good program that doesn't add to our nation's debt. The only way our program can remain a no-cost one is to preserve an import quota. Ideally, we would like to see the quota remain around 1 million tons. With domestic consumption at 7.37 short tons and on a slight declining trend, and current production around 6.48 million short tons, simple math suggests that if Mother Nature is good to all of us, both sugarcane and sugar beet growers during the same year could possibly produce more sugar than we need for domestic consumption. At that point, the program develops cost implications and destroys one of the key benefits to the government for keeping the program intact.

It's time we consider production constraints in order to maintain an import quota. We need to be unified in presenting a workable plan in order to prevent the government from forcing upon us a sugar program we don't want.

You have a responsibility to work with your suppliers in bringing together a unified voice to keep a workable domestic sugar program intact. We want a no-cost program that benefits consumers and taxpayers as well as sugarcane and beet growers.

PHENOTYPIC CHARACTERISTICS OF THE HYBRIDS  
OF SUGARCANE x RELATED GRASSES

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Canal Point, Florida

ABSTRACT

Data on stalk diameter and four measures of juice quality - Brix, percent sucrose, percent purity and kilograms of sugar per metric ton of cane (S/T) - were used to evaluate characteristics of the F<sub>1</sub> hybrid seedlings obtained by crossing sugarcane (a complex hybrid of Saccharum spp.) with related genera (Miscanthus and Erianthus). Both Miscanthus and Erianthus were used as male parents. The results indicated that the thin stalk and low sucrose content of the F<sub>1</sub> hybrids were strongly influenced by Miscanthus and Erianthus. The coefficients of variation showed the variability among these F<sub>1</sub> families was fairly uniform. The percentage of acceptable F<sub>1</sub> hybrids was very low. Therefore, selection for superior seedlings among the F<sub>1</sub> hybrids would not be very efficient. In order to obtain commercially acceptable clones, the superior F<sub>1</sub> clones will need to be repeatedly backcrossed or intercrossed with rigid selection for agronomic type.

INTRODUCTION

Saccharum, Erianthus, Miscanthus, Narenga and Sclerostachya are closely related genera and may be involved in the origin of sugarcane (3,5,6,7,15). The high polyploidy in Saccharum has resulted in the removal of the main obstacles to hybridization with other genera within the complex (8). Miscanthus and Erianthus are of great interest because of their wide adaptation, relatively high stalk numbers, excellent ratooning ability, and disease resistance (4,10,11,12,13). Some Miscanthus clones also show superior cold tolerance (12,13). Intergeneric crosses have enabled sugarcane breeders to introduce various heritable traits from other genera into the progeny of Saccharum (4,8,10,11,13). These intergeneric hybrids usually exhibit greater hybrid vigor than do interspecific crosses within Saccharum. Intergeneric hybrids may potentially serve as foundation breeding stocks and increase the hybrid vigor of cultivated sugarcane in the future (10). Loh and Hu (13) believe that sugarcane breeders in the sub-tropical countries are more interested in intergeneric crosses due to wide temperature extremes in those areas. Grassl (6) has also suggested that intergeneric hybridization offers the greatest promise for further improvement of existing germplasm.

Stokes and Tysdale (18) examined the parentages of some Canal Point (CP) varieties and found that only a few clones were prominent in all crosses. They were concerned whether progress in the breeding might be limited by the narrow germplasm base. More recently, Tai and Miller (20) expressed a similar concern about the narrow genetic base of the CP varieties. This limited genetic base may increase vulnerability of the sugar industries to disease epidemics (19). Interspecific and intergeneric hybridization with new basic germplasm could broaden the genetic base upon which current commercial cultivars are based (4,5,8,9,10,11,13). However, intergeneric hybridization in sugarcane is limited by the need to improve juice quality and undesirable agronomic traits of the F<sub>1</sub> progenies while trying to maintain the desirable characteristics from the related genera. Information on the genetic behavior of characters of economic importance is very limited (17). Studies on the genetic behavior of these traits in intergeneric hybrids are needed so that sugarcane breeders can confidently select their parental lines and to plan their breeding and selection strategy.

According to Li et al. (10) and Loh and Hu (13), two types of F<sub>1</sub> hybrids from a cross between sugarcane and Miscanthus can be obtained: Nobilized (normal) or female parent type (OOM) and intermediate or male parent type (OM). The OO and MM are used to represent the whole genetical constitution of sugarcane and Miscanthus, respectively. The female parent type, OOM, has a somatic chromosome number representing an unreduced gamete of female parent, cultivated sugarcane, plus the reduced gamete of the male parent, Miscanthus. The male parent type, OM, has a somatic chromosome number representing the reduced gametes of both parents. The female parent type has taller, thicker stalks, larger and wider leaves and relatively higher sugar content. The male parent type has slender stalks, narrower leaves and lower sugar content.



The objective of this study was to evaluate the variability in stalk diameter and components of juice quality of the F<sub>1</sub> hybrids of the male parent type obtained by crossing sugarcane and related genera.

#### MATERIALS AND METHODS

During the 1985-86 flowering season, two cultivated sugarcanes, CP 65-357 and NCo 310, were used as female parents to cross with two species of Erianthus (E. arundinaceus and E. procerus) and three species of Miscanthus (M. sinensis, M. floridulus and M. violaceum). Two clones of M. sinensis, "US 47-11" and "P I 3905", were used. Seeds were planted in sterilized muck soil in February 1986. One-month-old seedlings from these crosses were transplanted into styrofoam trays to promote root development and were kept in the greenhouse until May and then transplanted to the field. Seedlings were planted in single rows at 0.3 m intervals with 1.5 m between rows. Hybrid seedlings of the male parent type were identified on the basis of the morphological characteristics, such as thin stalk, narrow to medium leaves and profuse tillering (4,8,10,11,13). The number of hybrids of each cross varied from 5 (2% of the progeny) to 72 (28% of the progeny). Parental clones and self-pollinated seedlings of CP 65-357 and NCo 310 were also planted in the test as checks.

Stalk diameter (millimeters) was measured on five mature stalks per seedling at approximately 0.5 m above the ground at the mid-internode. Five to ten mature stalks from each seedling were cut for milling and crusher juice analysis in mid-December, 1986. Crusher juice Brix was determined with a hydrometer and percent sucrose by polarization (14). Percent purity was calculated as the ratio of percent sucrose to Brix. Calculation of the theoretical yield of sugar (kilograms of sugar per metric ton of cane, S/T) was conducted according to Winter-Carp-Greelg formula as modified by Arceneaux (2).

The analysis of variance for the intergeneric crosses with equal and unequal numbers of seedlings was used for the data of this study (16). Each seedling plant was used as one observation or replication. Two sets of multiple range tests (16),  $n=5$  and  $n=17$ , were conducted to compare the difference of means among crosses.

#### RESULTS AND DISCUSSION

The mean stalk diameter and four juice quality traits of parental clones, selfed and F<sub>1</sub> hybrid seedlings are shown in Table 1. The mean stalk diameter of selfed seedlings from both CP 65-357 and NCo 310 was smaller than that of their respective parent, but the selfed seedlings had larger stalk diameters than did any group of the F<sub>1</sub> hybrid seedlings. The average stalk diameter of the F<sub>1</sub> hybrid seedlings of sugarcane x Miscanthus were approximately 4 mm larger than the male parent, Miscanthus. The stalk diameter of the sugarcane x Erianthus hybrids showed little change when compared with the male parent, Erianthus. The results indicated that the thin stalk of Miscanthus and Erianthus appeared to be dominant over the thick stalk of commercial type sugarcane.

The average Brix for the F<sub>1</sub> hybrids of the intergeneric crosses appeared to be very similar to one another with a range of 8.9° to 10.5°. Brix values for the hybrid seedlings were slightly lower than the Brix of the selfs of CP 65-357 and NCo 310, but were slightly higher than their Miscanthus and Erianthus parents. The average Brix of selfed seedlings was less than those of their sugarcane parents. The percent sucrose of Miscanthus and Erianthus was very low compared with that of CP 65-357 and NCo 310. The F<sub>1</sub> hybrids had a two or three fold increase in sucrose content of their Miscanthus and Erianthus parents, but were much lower than the cultivated sugarcanes. The selfed seedlings of CP 65-357 and NCo 310 had a higher sucrose content than did the intergeneric F<sub>1</sub> hybrids. The crusher juice purity of both Miscanthus and Erianthus was very low. Their F<sub>1</sub> hybrids showed markedly improved purity which was still lower than that from the selfed seedlings of either CP 65-357 or NCo 310. The calculated sugar yields (S/T) were zero for Miscanthus, Erianthus and some F<sub>1</sub> hybrids because of their low percent sucrose and poor juice purity. The average sugar yield for the F<sub>1</sub> hybrids was very low and ranged from 9.36 kgs to 26.40 kgs. Selfed seedlings of CP 65-357 and NCo 310 produced 49.06 kgs and 45.49 kgs., respectively, while their parental clones, CP 65-357 and NCo 310, yielded 111.08 kgs and 72.07 kgs, respectively. The results indicated that the crusher juice quality of the F<sub>1</sub> hybrid seedlings was greatly reduced in comparison with the cultivated sugarcane parents. The characters of the F<sub>1</sub> hybrids showed the dominance of Miscanthus and Erianthus with low juice quality.



The coefficients of variation (CV) of the selfed and F<sub>1</sub> hybrid seedlings (Table 1) varied among the five traits examined: Low CV for stalk diameter and Brix; moderately low CV for sucrose content and percent purity and high CV for S/T. The selfed seedlings of both CP 65-357 and NCo 310 gave about the same magnitude of variation as did the F<sub>1</sub> hybrids from NCo 310 x Miscanthus crosses. The F<sub>1</sub> hybrids of sugarcane x Erianthus, however, produced higher CV's than did the other two groups of seedlings in most of the five traits examined. The low to moderate genetic variability as shown by the CV's for both stalk diameter and sucrose content suggested that selection for these two traits might not be very effective in the F<sub>1</sub> seedling stage and conversely most progress could be made selecting for S/T.

Table 1. Stalk diameter and measures of crusher juice quality of the parental clones and their selfed and F<sub>1</sub> hybrid seedlings.

	Stalk diameter		Brix		Sucrose		Purity		S/T	
	$\bar{X}$ (mm)	CV (%)	$\bar{X}$ (°)	CV (%)	$\bar{X}$ (%)	CV (%)	$\bar{X}$ (%)	CV (%)	$\bar{X}$ (kg)	CV (%)
<b>Parents</b>										
CP 65 357	29.00	-	18.16	-	15.85	-	86.49	-	111.08	-
NCo 310	27.00	-	13.08	-	10.84	-	83.71	-	72.07	-
<u>E. arundinaceus</u>	20.00	-	10.22	-	1.33	-	14.35	-	0.00	-
<u>E. procerus</u>	14.00	-	7.92	-	1.78	-	22.62	-	0.00	-
<u>M. sinensis</u>										
"US 47-11"	8.37	-	7.00	-	1.31	-	18.71	-	0.00	-
<u>M. sinensis</u>										
"PI 3905"	10.05	-	6.00	-	0.95	-	15.83	-	0.00	-
<u>M. floridulus</u>	11.00	-	7.20	-	1.40	-	19.40	-	0.00	-
<u>M. violaceum</u>	10.04	-	6.40	-	0.98	-	15.31	-	0.00	-
<b>Selfs or F<sub>1</sub> hybrids</b>										
CP 65-357 selfs	22.25	14.89	12.52	13.38	8.79	24.40	69.99	18.73	49.06	36.32
CP 65-357 x <u>E. arund-</u> <u>inaceus</u>	17.00	19.95	10.58	9.62	5.85	23.86	54.75	15.70	26.40	40.33
NCo 310 selfs	20.18	14.68	11.90	16.62	8.24	26.67	68.63	16.42	45.49	36.55
NCo 310 x <u>E. arund-</u> <u>inaceus</u>	14.86	9.85	9.43	13.97	3.70	44.38	37.84	33.73	10.40	100.00
NCo 310 x <u>E. procerus</u>	15.25	14.72	9.44	14.32	4.24	46.08	43.38	32.00	14.63	101.82
NCo 310 x <u>M. sinensis</u>										
"US 47-11"	13.96	12.51	8.93	12.31	3.39	31.48	37.42	24.52	9.36	71.26
NCo 310 x <u>M. sinensis</u>										
"PI 3905"	15.52	13.19	9.54	15.42	4.40	31.44	43.38	22.72	15.50	69.75
NCo 310 x <u>M. flori-</u> <u>dulus</u>	14.83	13.33	8.88	15.90	3.70	39.69	40.77	31.43	11.29	95.83
NCo 310 x <u>M. violaceum</u>	15.45	13.19	9.92	15.42	4.32	31.44	43.19	22.72	14.66	69.75

Two traits, stalk diameter and percent sucrose, were used to illustrate the differences among the selfed and F<sub>1</sub> hybrid seedlings using the Duncan's New Multiple Range Test (Table 2). With n=5, stalk diameter of CP 65-357 self was significantly larger than that of NCo 310 self and the F<sub>1</sub> hybrids. The mean stalk diameter of NCo 310 self was significantly larger than those of some F<sub>1</sub> hybrids, but was not significantly larger than that of other F<sub>1</sub> hybrids. There were no significant differences among the intergeneric crosses. When the sample size was increased to 17, two crosses, CP 65-357 x E. arundinaceus and NCo 310 x E. arundinaceus were excluded from the multiple range test. The results indicated that the average stalk diameters of CP 65-357 selfs were significantly larger than that of NCo 310 selfs. The diameter of both selfs were significantly larger than those of any of the intergeneric crosses. There were no significant differences among the intergeneric crosses. Percent sucrose showed a similar pattern over the two sample sizes as did stalk diameter. With n=5, there was no significant difference between CP 65-357 selfs and NCo 310 selfs, but both were significantly different from all intergeneric crosses except CP 65-357 x E. arundinaceus which was significantly different from CP 65-357 self, but not significantly different from NCo 310 self. CP 65-357 x E. arundinaceus might potentially produce hybrids with high sucrose content and would be of great interest to sugarcane breeders. When the sample size was increased

to 17 selfs of CP 65-357 and NCo 310 had higher percent sucrose than all the intergeneric crosses. There was a significant difference between these two groups, but there were no significant differences within each group. The results indicated that the F<sub>1</sub> seedlings from crosses with Miscanthus and Erianthus as male parents did not show a significant difference in percent sucrose among species. However, caution should be taken in interpreting the data because most of the sample sizes were small.

Table 2. Means of stalk diameter and percent sucrose of selfed and F<sub>1</sub> hybrid seedlings at two sample sizes, n=5 and n=17.

Cross	Stalk diameter (mm)		Sucrose(%)	
	n = 5	n = 17	n = 5	n = 17
CP 65-357 selfs	21.60 a <sup>1/</sup>	22.59 a	8.53 a	8.55 a
CP 65-357 x <u>E. arundinaceus</u>	17.00 bc	- 2/ <sup>2/</sup>	5.85 bc	- 2/ <sup>2/</sup>
NCo 310 selfs	18.40 b	20.18 b	8.09 ab	8.24 a
NCo 310 x <u>E. arundinaceus</u>	15.40 bc	- 2/ <sup>2/</sup>	3.59 c	- 2/ <sup>2/</sup>
NCo 310 x <u>E. procerus</u>	14.80 c	15.35 c	5.28 c	4.46 b
NCo 310 x <u>M. sinensis</u> "US 47-11"	15.00 bc	13.82 c	3.81 c	3.60 b
NCo 310 x <u>M. sinensis</u> "PI 3905"	15.00 bc	14.94 c	5.05 c	4.20 b
NCo 310 x <u>M. floridulus</u>	14.20 c	14.88 c	4.54 c	3.62 b
NCo 310 x <u>M. violaceum</u>	14.60 c	15.59 c	3.83 c	4.23 b

<sup>1/</sup> Means within a column followed by the same letter do not differ significantly at the 5% level according to Duncan's New Multiple Range Test.

<sup>2/</sup> Excluded from Duncan's New Multiple Range Test.

Seedling data on the stalk diameter and percent sucrose of NCo 310, respectively and three intergeneric crosses (NCo 310 x M. sinensis "US 47-11" x M. floridulus; and M. violaceum) were used for a graphical examination of their population characteristics. The frequency distributions of the stalk diameter of the four populations are shown in Figure 1. NCo 310 selfs were fairly normal distributed with a range of 14 mm and a mode at 19 mm. The F<sub>1</sub> hybrids of the intergeneric crosses showed some differences in range and mode. NCo 310 x M. sinensis "US 47-11" and NCo 310 x M. floridulus produced F<sub>1</sub> hybrids with the same mode at 13 mm, but with a different range. NCo 310 x M. floridulus and NCo 310 x M. violaceum produced F<sub>1</sub> hybrids with the same range of distribution, but with different modes. The frequency distribution of the F<sub>1</sub> hybrids of NCo 310 x M. violaceum were skewed slightly toward a larger stalk diameter. The F<sub>1</sub> hybrids of the other two intergeneric crosses appeared to be fairly normal distributed. The most often observed stalk diameters among the F<sub>1</sub> hybrids were between 13 mm and 17 mm. The most often observed stalk diameter among the selfed seedlings of NCo 310 was 19 mm. Very few hybrids had a stalk diameter exceeding 19 mm in the seedling stage and the trait of thin stalks in the F<sub>1</sub> hybrids was inherited from Miscanthus. The F<sub>1</sub> hybrids of sugarcane x Erianthus also showed inheritance patterns similar to that of sugarcane x Miscanthus.

The frequency distributions of % sucrose of one selfed and three F<sub>1</sub> hybrid populations are shown in Figure 2. The % sucrose of selfed seedlings of NCo 310 had two modes. These results suggested that selfed seedlings of NCo 310 would segregate into at least two groups of sucrose content. Among the three F<sub>1</sub> hybrids, NCo 310 x M. violaceum hybrids appeared to give wider range of distribution than did the other two crosses. NCo 310 x M. sinensis "US 47-11" produced F<sub>1</sub> hybrids with two modes while the other two crosses, NCo 310 x M. violaceum and NCo 310 x M. floridulus each had a single mode (3.5% and 4.5%, respectively). The F<sub>1</sub> hybrids of NCo 310 x M. violaceum showed a marked skewness toward the higher percent sucrose.

Sugarcane breeders are most interested in the percentage of clones with a minimum acceptability level in their breeding progenies. Data on stalk diameter and % sucrose were used for such an analysis. Table 3 shows the percentage of acceptable seedlings following selection for the stalk diameter at the culling level of 19 mm and for the sucrose content at the culling level of 5% imposed in the selfs and F<sub>1</sub> hybrids.

In both CP 65-357 selfs and NCo 310 selfs, more than 70% of their seedlings were acceptable, whereas in NCo 310 x Miscanthus crosses, less than 10% of their F<sub>1</sub> hybrid seedlings were acceptable. The NCo 310 x E. procerus cross also did not produce a very high percentage of acceptable seedlings (4%). CP 65-357 x E. arundinaceus appeared to produce a relatively high percentage of acceptable seedlings (33.33%), but none of the F<sub>1</sub> hybrid seedlings of NCo 310 x E. arundinaceus was acceptable. For the sucrose content at the culling level of 5%, all seedlings of CP 65-357 self and NCo 310 self would be acceptable, but the acceptable F<sub>1</sub> hybrid seedlings varied from 3% to 83%. Sugarcane x E. arundinaceus did produce relatively high percentages of acceptable F<sub>1</sub> hybrids.

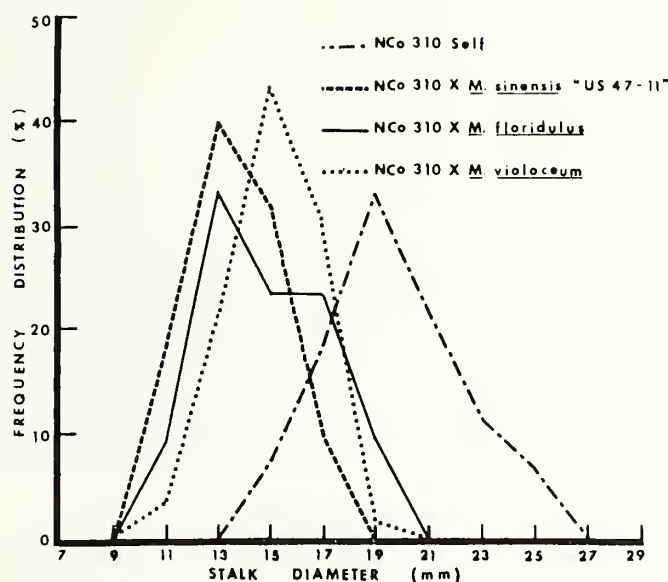


Figure 1. Frequency distribution for stalk diameter in seedling crop of NCo 310 selfs and three intergeneric crosses between NCo 310 and Miscanthus.

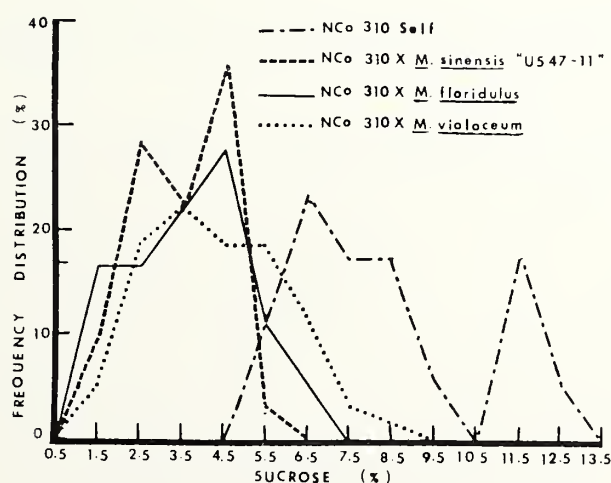


Figure 2. Frequency distribution for sucrose content (%) in seedling crop of NCo 310 selfs and three intergeneric crosses between NCo 310 and Miscanthus.

Table 3. The percentage of the acceptable seedlings at three culling levels for stalk diameter (19 mm, 20 mm and 21 mm) and sucrose content (5%, 6% and 7%).

Selfs or F <sub>1</sub> hybrids	Stalk diameter			Sucrose content		
	>19 mm	>20 mm	>21 mm	>5%	>6%	>7%
	(%)	(%)	(%)	(%)	(%)	(%)
CP 65-357 selfs	90	80	63	100	88	83
CP 65-357 x <u>E. arundinaceus</u>	33	33	17	83	60	20
NCo 310 selfs	77	60	40	100	88	65
NCo 310 x <u>E. arundinaceus</u>	0	0	0	29	0	0
NCo 310 x <u>E. procerus</u>	4	0	0	20	14	14
NCo 310 x <u>M. sinensis</u> "US 47-11"	0	0	0	3	0	0
NCo 310 x <u>M. sinensis</u> "PI 3905"	5	0	0	20	10	5
NCo 310 x <u>M. floridulus</u>	10	10	0	15	5	0
NCo 310 x <u>M. violaceum</u>	0	0	0	35	17	5

Since the frequency of F<sub>1</sub> hybrids from crosses between sugarcane and related genera produced acceptable levels of stalk diameter and % sucrose at a very low frequency, selection of F<sub>1</sub> hybrids in seedling crops should be carried out with caution. The rigorous selection criteria should be applied to F<sub>2</sub> or BC<sub>1</sub> seedlings, when more genetic variability would be created by the segregation and recombination of genes (1). Most of the economically important traits in sugarcane are quantitative ones, controlled by multiple genes (17). A large population of F<sub>2</sub> or BC<sub>1</sub> plants would be needed to obtain segregants with desirable combinations of agronomic traits.

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## CONTROL OF JOHNSONGRASS IN FALLOWED SUGARCANE FIELDS

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### ABSTRACT

Preemergence herbicide treatments were evaluated for the control of seedling johnsongrass [*Sorghum halepense* (L.) Pers.], and other weeds in raised beds of fallowed sugarcane (*Saccharum* intraspecific hybrids) fields. Herbicidal efficacy was determined by a visual estimate of weed cover, i.e. the percent of the plot surface covered by green foliage. Surface applications of terbacil [5-chloro-3-(1,1-dimethylethyl)-6-methyl-2,4(1H,3H)-pyrimidine dione], metribuzin [4-amino-6-(1,1-dimethylethyl)-3-(methylthio)-1,2,4-triazin-5(4H)-one], or fenac (2,3,6-trichlorobenzene acetic acid) provided effective (>80% reduction in foliage cover) control of johnsongrass and other weeds eight weeks after treatment (WAT). Heavy infestations of junglerice [*Echinochloa colonum* (L.) Link] (1982 and 1984) and sprawling panicum [*Urochloa reptans* L. Stapf.] (1983) severely suppressed the growth and development of johnsongrass in untreated plots. By 12 WAT the degree of johnsongrass control resulting from this suppression often equaled that obtained in the herbicide-treated plots where the growth of escaped johnsongrass was unrestricted by competing annual weeds which continued to be controlled. To minimize the growth and maturation of escapes, postemergence herbicide treatments would also have to be employed, especially where complete control of highly competitive weeds such as johnsongrass is the objective. The effect of these herbicides on the growth of the newly-planted sugarcane was not evaluated in this study.

### INTRODUCTION

Gradual succession of plant communities in the sugarcane fields of Louisiana is a common occurrence, with the existence of any one community depending on climatic conditions and artificial disturbances (tillage and/or herbicide usage). Johnson-grass is one of the first weeds in the summer community to emerge in the spring because both seed and rhizome buds germinate at temperatures as low as 20°C (13), typical temperatures for early spring in Louisiana. This early emergence allows johnsongrass and sugarcane to co-dominate the weed-crop community within the planted row and allows johnsongrass to dominate the weed community between the planted sugarcane rows and in fallowed fields.

In Louisiana, sugarcane ratoons are destroyed by disking following the harvest of the second ratoon crop. Fields are then fallowed through the spring and summer months until being replanted. During the fallow period, various methods of mechanical tillage are used to a) destroy old stubble, which may be diseased, and johnsongrass rhizomes, b) deplete the soil seed bank, and c) repair harvesting scars. Rows are reestablished in the late spring and are opened and closed at timely intervals throughout the summer to continue the fallow program until planting. As a result, fallowed sugarcane fields are usually disked and/or plowed six to eight times between harvest and row-buildup. McWhorter (7) found that to be successful in controlling johnsongrass developing from seed and/or rhizomes, diskings had to be performed before plants reached the age of three weeks. At least six frequent diskings in the early spring were required to dehydrate and destroy johnsongrass rhizomes (8).

Rainfall often prevents timely disking in the summer, allowing seedling johnsongrass to produce seed and develop rhizomes, which effectively cancels efforts early in the season to decrease weed reserves in the soil. Control of competitive weeds like johnsongrass in the 60- to 90-day period between row buildup and planting would serve to prevent replenishment of weed seed and rhizome reserves during extended periods of precipitation when mechanical weed control is not feasible.

Preemergence herbicides have been used for the control of weeds in fallow fields of other crops (2,3,5,6). Herbicide programs for fallowed wheat and oat fields

in arid regions provide broad spectrum weed control in the interim between harvest and replanting. In these regions, tillage is discouraged because it encourages wind and water erosion of soil and depletes soil moisture. The preemergence herbicides atrazine [6-chloro-N-ethyl-N'-(1-methylethyl)-1,3,5-triazine-2,4-diamine] (6,9,14,15); metribuzin (3); prometon [6-methoxy-N,N'-bis(1-methylethyl)-1,3,5-triazine-2,4-diamine] (5); and propazine [6-chloro-N,N'-bis(1-methylethyl)-1,3,5-triazine-2,4-diamine] (9) have been used to successfully control annual weeds in fallowed fields for as long as ten months. The present study was initiated to evaluate the feasibility of using preemergence herbicides to control johnsongrass and other weeds in fallowed sugarcane fields in the interim between row build-up and replanting.

#### MATERIALS AND METHOD

Studies were conducted on Sharkey clay (Vertic Haplaquepts; very-fine, montmorillonitic, nonacid, thermic) in 1982, 1983, and 1984 and also on a Mhoon silt loam (Typic Fluvaquents; fine-silty, mixed, nonacid, thermic) in 1984 on fallowed sugarcane fields having a history of severe johnsongrass (rhizome and seed) infestations in the second ratoon crop. Typical plantation practices were used for the management of fallowed land. These practices included: destroying the second ratoon immediately after the October harvest by two diskings with a disk-harrow; redisking at timely intervals (at least three times beginning in mid to late March); and land leveling in May. Following land leveling, 1.8 m rows were marked with a double-lister plow and hipped using two passes with a disk chopper. The resulting rows were 25 to 30 cm high with relatively flat tops approximately 90 cm in width. The herbicides metribuzin, terbacil, pendimethalin [N-(1-ethyl-propyl)-3,4-dimethyl-2,6-dinitrobenzenamine], oryzalin [4-(dipropylamino)-3,5-dinitrobenzenesulfonamide], hexazinone [3-cyclohexyl-6-(dimethylamino)-1-methyl-1,3,5-triazine-2,4(1H,3H)-dione], and fenac were applied after row buildup as broadcast, aqueous sprays at a carrier volume of 187 l/ha to weed-free, clod-free beds on June 2, 1982, June 22, 1983, and June 13, 1984. The plots received no further tillage after herbicide treatment.

The experimental design consisted of a randomized complete block design with five (1983) or six (1982 and 1984) replicates per treatment. Experimental plots were three rows 5.3 m wide by 12.2 m (1982 and 1983) or 15.2 m (1984) long.

Herbicidal efficacy was determined four (1982), eight (1982, 1983, and 1984), and twelve (1983 and 1984) weeks after treatment (WAT) by estimating weed cover of johnsongrass and the complexes of the other grass and broadleaf weeds that were present. Weed cover represented a visual estimate of the percent of the plot's surface covered by green tissue of each weed species or complex. Assessing herbicidal efficacy based on species density, height measurements, biomass, or seed production is time consuming and subject to variability due to nonuniform spatial distribution. Scanning plots and estimating foliar cover was shown to be a rapid and relatively accurate means of estimating infestation levels (reproductive capabilities) of plants because species, populations and size are used in the visual estimate of plot coverage (4). Since the entire plot is scanned, variability due to differences in spatial distribution within the plot is also reduced.

#### RESULTS AND DISCUSSION

In these studies, the mechanical operations used in the interim between ratoon destruction and row buildup were adequate to destroy the majority of the johnsongrass rhizomes. Grasses that became problems thereafter and were the targets for control by the herbicide treatments were seedling johnsongrass and the small-seeded grass complex consisting of junglerice (80% of the total weed cover for the annual grass complex in 1982 and 1984) and lesser infestation levels of crabgrass [*Digitaria sanguinalis* (L.) Scop.] and goosegrass [*Eleusine indica* (L.) Gaertn.]. In 1983, sprawling panicum was the dominant species (70% of the total cover) in the grass complex. The broadleaf weed complex consisted of hemp sesbania [*Sesbania exaltata* (Raf.) Cory] (1982 only), wild poinsetta (*Euphorbia heterophylla* L.), cutleaf groundcherry (*Physalis angulata* L.), pitted morningglory (*Ipomoea lacunosa* L.), and scarlet morningglory (*Ipomoea coccinea* L.). Cutleaf groundcherry and scarlet morningglory were the dominant broadleaf weeds in all years.

Intra-specific weed competition within a plant community was demonstrated in this study when the results of the atrazine treatment were compared with the



untreated check. In the untreated plots, johnsongrass contributed 10 to 29 percent of the total weed cover at the last rating date, whereas in plots receiving only atrazine, johnsongrass contributed 70 to 87 percent of the estimated weed cover (Tables 1, 2, 3 and 4).

Acceptable (>80%) reductions in johnsongrass foliar cover were observed with all treatments except atrazine 4 WAT in 1982 (Table 1). Since a distinction between herbicide treatments could not be made 4 WAT, this evaluation period was dropped in subsequent years in favor of rating 8 and 12 WAT. These rating periods corresponded to mid-August (8 WAT) and mid-September (12 WAT) sugarcane planting dates. In 1982, the 32 percent foliar cover of johnsongrass comprised 53 percent of the total weed cover at 4 WAT in the atrazine-treated plots. By 10 WAT this percentage had increased to 427 percent or 70 percent of the total weed cover (Table 1). Because the soil remained undisturbed after treatment, this increase in cover resulted primarily from unrestricted growth rather than additional germination. In the untreated plots, where the emergence of small-seeded grass (primarily junglerice) and broadleaf weeds restricted the development of johnsongrass, the percent of total cover contributed by johnsongrass remained relatively unchanged between the 4 and 10 WAT rating periods (Table 1). All treatments provided good early season control of junglerice and other small-seeded annual grasses; however, atrazine, hexazinone, and terbacil failed to provide acceptable small-seeded annual grass control by 10 WAT (Table 1).

Table 1. Total weed cover and foliar cover of johnsongrass (JG) and small-seeded annual grasses (AG) in fallowed sugarcane fields in 1982.<sup>1/2/3/</sup>

Herbicide(s)	Rate(s)	4 WAT			10 WAT		
		Total	JG	AG <sup>4/</sup>	Total	JG	AG <sup>4/</sup>
	(kg/ha)	- - - - - (%) - - - - -					
Untreated-ck	--	161( 0)a	26(19)a	122 a	350( 0)b	35(92)f	265 a
Atrazine	2.2	61(62)b	32( 0)a	28 b	613( 0)a	427( 0)a	178 b
Pendimethalin + atrazine	2.2 + 2.2	4(98)de	2(94)b	2 d	340( 3)b	235(45)b	70 de
Pendimethalin + atrazine	3.4 + 2.2	3(98)e	1(97)b	1 d	221(37)c	134(69)de	35 ef
Oryzalin + atrazine	2.2 + 2.2	8(95)cde	5(84)b	2 d	222(37)c	145(66)cde	37 ef
Oryzalin + atrazine	3.4 + 2.2	5(97)de	2(94)b	2 d	202(42)cd	89(79)ef	20 ef
Hexazinone	0.9	20(88)c	2(94)b	16 c	354( 0)b	216(49)bc	116 cd
Hexazinone	1.7	--	--	--	--	--	--
Terbacil	1.7	50(69)b	5(84)b	38 b	415( 0)b	172(60)bcd	228 ab
Terbacil	2.2	17(89)cd	3(91)b	10 cd	242(31)c	107(75)def	122 c
Metribuzin	1.7	1(99)e	0(100)b	1 d	119(66)d	85(80)ef	11 f

<sup>1/</sup> Means within columns followed by the same letter are not significantly different at the 5% level according to the LSD test of significance.

<sup>2/</sup> Total weed cover represents the sum of the individual estimates of weed cover of johnsongrass, annual grasses, and broadleaf weeds.

<sup>3/</sup> Numbers in parenthesis represent the percent reduction in weed cover. To assess the effects of the various herbicides on total weed cover production, the untreated check was used to represent no control. To determine the degree of johnsongrass control obtained with the various treatments, johnsongrass weed cover in the atrazine treated plot was used to represent no control.

<sup>4/</sup> Junglerice was the predominant species in the AG complex.



In 1983, sprawling panicum was the major small-seeded annual grass, contributing 86 and 148 percent to the total weed cover 8 and 12 WAT, respectively. All treatments provided excellent (>90%) control of this weed 8 WAT. When compared with the atrazine-treated plots, the herbicide treatments also provided good to excellent (>78%) control of seedling johnsongrass 8 WAT (Table 2). Control in all cases was nearly two-fold greater than the 42% johnsongrass suppression obtained 8 WAT by the untreated natural community of sprawling panicum and broadleaf weeds. By 12 WAT, johnsongrass control in plots treated with hexazinone (1.7 kg/ha), terbacil, metribuzin, and fenac (5.6 kg/ha) continued to be significantly higher than the natural suppression observed in the untreated check (Table 2).

Table 2. Total weed cover and foliar cover of johnsongrass (JG) and small-seeded annual grasses (AG) in fallowed sugarcane fields in 1983.<sup>1/2/3/</sup>

Herbicide(s)	Rate(s)	8 WAT			12 WAT		
		Total	JG	AG <sup>4/</sup>	Total	JG	AG <sup>4/</sup>
	(kg/ha)	- - - - - (%) - - - - -					
Untreated	--	194(0)a	64(42)b	86 a	210(0)a	38(72)c	148 a
Atrazine	2.2	120(37)b	110(0)a	7 b	154(27)b	135(0)a	17 bcd
Pendimethalin + atrazine	2.2 + 2.2	25(87)c	24(78)c	1 c	77(63)c	64(53)b	12 cde
Pendimethalin + atrazine	3.4 + 2.2	22(88)c	18(84)c	3 bc	37(82)efg	27(80)c-f	7 de
Oryzalin + atrazine	2.2 + 2.2	22(88)c	21(81)c	0 c	44(79)def	34(75)cd	5 de
Oryzalin + atrazine	3.4 + 2.2	9(95)c	9(92)c	0 c	18(91)c-h	17(87)c-f	0 e
Hexazinone	0.9	15(92)c	10(91)c	2 bc	35(83)efg	30(78)cde	2 de
Hexazinone	1.7	2(99)c	2(98)c	0 c	3(99)h	3(98)f	1 e
Terbacil	1.7	15(92)c	12(89)c	2 bc	46(78)de	15(89)c-f	26 bc
Terbacil	2.2	5(97)c	4(96)c	1 c	14(93)fgh	7(95)ef	7 de
Metribuzin	1.7	3(99)c	1(99)c	0 c	16(92)e-h	6(96)f	2 de
Metribuzin	2.2	6(97)c	3(97)c	0 c	8(96)gh	5(96)f	1 e
Fenac	3.4	18(91)c	10(91)c	2 bc	72(66)cd	31(77)cd	28 b
Fenac	5.4	2(99)c	2(98)c	0 c	35(83)efg	11(92)def	15 b-e

<sup>1/</sup> Means within columns followed by the same letter are not significantly different at the 5% level according to the LSD test of significance.

<sup>2/</sup> Total weed cover represents the sum of the individual estimates of weed cover of johnsongrass, annual grasses and broadleaf weeds.

<sup>3/</sup> Numbers in parenthesis represent the percent reduction in weed cover. To assess the effects of the various herbicides on total weed cover production, the untreated check was used to represent no control. To determine the degree of johnsongrass control obtained with the various treatments, the johnsongrass weed cover in the atrazine treated plot was used to represent no control.

<sup>4/</sup> Sprawling panicum was the predominant species in the AG complex.

In 1984, junglerice again predominated the small-seeded annual grass complex on both soil types and contributed 208 (clay) and 174 (silt-loam) percent of the total weed cover 8 WAT (Tables 3 and 4). These percentages remained essentially

unchanged 12 WAT indicating that junglerice relative dominance in the community was established by early August. At 8 WAT, johnsongrass inhibition resulting from suppression by the small-seeded annual weed complex resulted in fair (67%) control of johnsongrass on clay soil (Table 3). Only terbacil, metribuzin, and fenac provided significantly higher johnsongrass control 8 WAT with all herbicidal treatments providing good to excellent control of the annual grass complex.

At 12 WAT, the johnsongrass control on the clay soil was no better with the various herbicide treatments than that resulting from suppression by the annual weed community in the untreated check (Table 3). The reduced level of control in the herbicide-treated plots resulted from increased production of johnsongrass biomass facilitated by the control of the annual grass and broadleaf weed complexes by the herbicides.

Table 3. Total weed cover and foliar cover of johnsongrass (JG) and small-seeded annual grasses (AG) in fallowed sugarcane fields in 1984: Sharky clay soil.<sup>1/2/3/</sup>

Herbicide(s)	Rate(s)	8 WAT			12 WAT		
		Total	JG	AG <sup>4/</sup>	Total	JG	AG <sup>4/</sup>
	(kg/ha)	----- (%) -----					
Untreated	--	328( 0)a	78(67)b-e	208 a	418( 0)a	85(73)d-g	267 a
Atrazine	2.2	303( 8)a	233( 0)a	62 b	440( 0)a	312( 0)a	98 b
Pendimethalin + atrazine	2.2 + 2.2	119(64)cd	88(62)bcd	24 cd	174(58)bcd	133(57)bcd	31 cde
Pendimethalin + atrazine	3.4 + 2.2	103(69)cde	94(60)bc	2 e	114(73)d-g	104(67)c-g	2 e
Oryzalin + atrazine	2.2 + 2.2	126(62)c	105(55)bc	5 de	184(56)bc	148(53)bc	6 e
Oxyzalin + atrazine	3.4 + 2.2	105(68)cde	81(65)bcd	3 de	161(61)cde	125(60)b-e	10 de
Hexazinone	0.9	178(46)b	122(48)b	40 c	228(45)b	170(46)b	42 cd
Hexazinone	1.7	54(84)ef	42(82)def	5 de	130(69)c-f	119(62)b-f	8 de
Terbacil	1.7	64(80)ef	57(76)c-f	5 de	87(79)fg	75(76)d-g	4 e
Terbacil	2.2	30(91)f	27(88)ef	1 e	62(85)g	49(84)g	3 e
Metribuzin	1.7	48(85)f	27(88)ef	12 de	170(59)bcd	92(71)c-g	52 c
Metribuzin	2.2	31(91)f	21(91)f	6 de	100(76)efg	72(77)efg	16 de
Fenac	3.4	70(79)def	40(83)def	18 de	153(63)cde	69(78)efg	56 c
Fenac	5.4	24(93)f	16(93)f	6 de	139(67)c-f	63(80)fg	53 c

<sup>1/</sup> Means within columns followed by the same letter are not significantly different at the 5% level according to the LSD test of significance.

<sup>2/</sup> Total weed cover represents the sum of the individual estimates of weed cover of johnsongrass, annual grasses, and broadleaf weeds.

<sup>3/</sup> Numbers in parenthesis represent the percent reduction in weed cover. To assess the effects of the various herbicides on total weed cover production, the untreated check was used to represent no control. To determine the degree of johnsongrass control obtained with various treatments, the johnsongrass weed cover in the atrazine treated plot was used to represent no control.

<sup>4/</sup> Junglerice was the predominant species in the AG complex.

Similar results were obtained on the lighter silt loam soil with all herbicide treatments providing good to excellent control of seedling johnsongrass and the small-seeded annual weeds 8 WAT (Table 4). By 12 WAT, the competition from early emerging annual weeds in the untreated plots had resulted in a 78% suppression of johnsongrass. None of the herbicide treatments provided a significantly greater degree of control.

Table 4. Total weed cover and foliar cover of johnsongrass (JG) and small-seeded annual grasses (AG) in fallowed sugarcane fields in 1984: silt loam soil.<sup>1/2/3/</sup>

Herbicides(s)	Rate(s)	8 WAT			12 WAT		
		Total	JG	AG <sup>4/</sup>	Total	JG	AG <sup>4/</sup>
	(kg/ha)	----- (%) -----					
Untreated	--	362( 0)a	132(58)b	174 a	422( 0)b	122(78)def	193 a
Atrazine	2.2	320(12)a	312( 0)a	6 c	588( 0)a	565( 0)a	10 c
Pendimethalin + atrazine	2.2 + 2.2	80(78)bcd	75(76)c	6 c	296(30)bc	285(50)b	11 c
Pendimethalin + atrazine	3.4 + 2.2	86(76)bc	80(74)bc	6 c	292(31)bcd	276(51)b	11 c
Oryzalin + atrazine	2.2 + 2.2	59(84)cde	55(82)cde	4 c	177(58)c-f	158(72)cde	18 c
Oryzalin + atrazine	3.4 + 2.2	33(91)cde	31(90)cde	2 c	202(52)c-f	183(68)bcd	18 c
Hexazinone	0.9	67(81)b-e	64(79)cd	2 c	256(39)cde	240(58)bc	9 c
Hexazinone	1.7	134(63)b	82(74)bc	39 b	210(50)c-f	92(84)def	92 b
Terbacil	1.7	28(92)cde	16(95)de	1 c	159(62)d-g	112(80)def	12 c
Terbacil	2.2	16(96)cde	5(98)e	0 c	94(78)fg	38(93)f	7 c
Metribuzin	1.7	11(97)de	7(98)e	2 c	172(59)c-f	107(81)def	56 bc
Metribuzin	2.2	8(98)de	7(98)e	0 c	141(67)efg	93(84)def	30 c
Fenac	3.4	16(96)cde	11(96)de	5 c	96(77)fg	59(90)ef	18 c
Fenac	5.4	5(99)e	4(99)e	1 c	38(91)g	22(96)f	7 c

<sup>1/</sup> Means within columns followed by the same letter are not significantly different at the 5% level according to the LSD test of significance.

<sup>2/</sup> Total weed cover represents the sum of the individual estimates of weed cover of johnsongrass, annual grasses, and broadleaf weeds.

<sup>3/</sup> Numbers in parenthesis represent the percent reduction in weed cover. To assess the effects of the various herbicides on total weed cover production, the untreated check was used to represent no control. To determine the degree of johnsongrass control obtained with the various treatments, the johnsongrass weed cover in the atrazine treated plot was used to represent no control.

<sup>4/</sup> Junglerice was the predominant species in the AG complex.

These results indicate that use of the preemergence herbicides terbacil, metribuzin, and fenac may aid in controlling a broad spectrum of problem weeds including johnsongrass in fallowed sugarcane fields by providing eight to ten weeks of control. To continue this degree of control, these programs must be supplemented with the application of postemergence herbicides to control escaped johnsongrass prior to reproductive development. Such treatments could eliminate much of the

tillage now required and would give more consistent weed control. In addition, soil disturbance would be minimized, hence soil erosion would probably be reduced (1) and soil moisture conserved (6).

This study does not extend into the planting of sugarcane, and no data are presented on the germination of sugarcane or the tilth of the seed bed in which the sugarcane is planted. One of the disadvantages of using residual preemergence herbicide treatments in fallow land is the possibility of causing injury to newly planted sugarcane. Fenac applied at 6.7 kg/ha to fallow land prior to planting has been shown to cause significant injury to sugarcane roots (9). This injury was not observed in our plots where fenac was applied earlier, at lower concentrations, and under conditions of average rainfall, however.

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EFFECTIVENESS OF SCREENING FOR SMUT RESISTANCE IN THE  
SUGARCANE SELECTION PROGRAM IN LOUISIANA

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ABSTRACT

Resistance of sugarcane clones to smut was tested from 1982 to 1986 by immersing seed cane in a suspension of *Ustilago scitaminea* teliospores. In the initial 1982-1983 test, slightly more than half of the clones were considered to be susceptible, while the remainder were resistant or intermediate. Among clones selected for continued varietal testing, similar numbers of clones came from each disease reaction category. In each succeeding test, a new series of clones was added to those clones selected from earlier series. Increasing numbers of clones were rated resistant in each successive test. In the 1985-1986 test, over 50% of the clones were rated resistant to smut; among the clones selected in two or three previous selection and testing cycles, over 80% were resistant. No susceptible clone was selected for advancement from the 1985-1986 test. Resistant clones were identified among the progeny of parents not selected for resistance to smut.

INTRODUCTION

Smut resistance became a selection criterion in the sugarcane selection program at Houma, Louisiana, following the first observation of smut (*Ustilago scitaminea* Sydow) in 1981 (5). Although some management of susceptible clones is possible with roguing of smutted stools when the incidence is low or with hot-water treatment of seed cane to reduce initial disease levels in plant cane, an effective long-term control of smut has been the planting of resistant cultivars (1, 3, 6). Objectives of the sugarcane smut testing program in Houma are to identify smut resistance and to increase the frequency of resistant clones in the final stages of the selection program. Results of the smut testing program from 1982 to 1986 are reported.

MATERIALS AND METHODS

Inoculation of clones to test for resistance to sugarcane smut began in 1982. Clones to be tested were inoculated and planted each fall and examined for smut the next summer. The tests included clones from the Louisiana breeding program of the Louisiana Agricultural Experiment Station (L and LCP assignments) and from the USDA breeding program selected at Houma (CP assignments). The clones from the two programs are exchanged annually the year after they are given permanent accession numbers (2). CP cultivars were first tested the year after permanent accession number assignment, and the L and LCP cultivars the year following exchange of cultivars between the two breeding programs (2). Clones selected for further advancement in successive years were included every year until commercial release. The number of clones tested in the smut testing program at Houma from 1982 to 1986 is given in Table 1. From 1983 to 1985, clones were also tested in nonreplicated tests, but the results were not useful, and the practice has been discontinued (4).

Seed cane of each clone was inoculated by dipping 18 leaf-free stalks in a suspension of approximately  $5 \times 10^6$  teliospores per ml for 10 minutes, then planted immediately in the field. Spore viability, determined by germinating teliospores on water agar, ranged from 90 to 95%. The experimental design was a randomized block with three replications. Plots were 4.6m long and one row wide, planted on ridges 1.8m apart.

The experiments were planted in late summer at Houma, Louisiana. The fall growth was killed back by subfreezing temperatures during the winter months with uninterrupted growth resuming in March or April.

Plots were examined weekly and stalks with whips were counted and removed between the first of May and mid-July. All stalks in the plot, healthy and diseased, were counted separately when the final counts were made. Visible whips and grassy shoots (a symptom typically preceding whip formation) were included in the final count of diseased stalks. The percent diseased shoots was calculated for all clones from the final count of healthy shoots and the sum of all shoots that had whips during the growing season.

Table 1. Number of sugarcane clones tested in the smut testing program at Houma, Louisiana, from 1982 to 1986.

Test	CPs	Ls and LCPs	Standards
1982-1983	76	7	4
1983-1984	68	19	4
1984-1985	71	32	4
1985-1986	81	34	5

Clones were grouped into three disease reaction categories -- susceptible, intermediate, and resistant -- based on the incidence of smut-infected shoots. Commercial clones with known disease reactions under field conditions were included as standards, and the percentage of smut-infected shoots of each of these cultivars was used to determine the range of percentages to be included in each reaction category. The range of percentages was adjusted for each test using the reaction of standards.

Smut resistance was only one of a number of agronomic, physiological, and pathological characteristics used to select clones for advancement in the cultivar selection program.

#### RESULTS

The number of clones assigned to the three smut reaction categories in each test is given in Table 2. The clones in the 1982-1983 test had not been previously exposed to sugarcane smut. Slightly more than half the clones in the 1982-1983 test was assigned to the susceptible category (Table 2). There were more susceptible clones among the 80-series clones; otherwise the proportions of clones in each reaction category were similar. The number of clones advanced from each reaction category was about the same; however, proportionately more resistant and intermediate clones were advanced (Table 3).

Table 2. Number and proportion of clones assigned to each smut disease reaction category.

Series	Resistant		Intermediate		Susceptible	
	No.	%	No.	%	No.	%
1982-1983 Test						
75-79	7	23	10	33	13	43
80	6	27	1	5	15	68
81 <sup>1/</sup>	10	32	6	19	15	48
Total	23	28	17	20	43	52
1983-1984 Test						
77-80	5	24	7	33	9	43
81	16	64	4	16	5	20
82 <sup>1/</sup>	16	41	7	18	16	41
Total	37	44	18	21	30	35
1984-1985 Test						
79-81	12	57	6	29	3	14
82	15	36	10	24	17	40
83 <sup>1/</sup>	16	40	8	20	16	40
Total	43	42	24	23	36	35
1985-1986 Test						
79-82	24	83	5	17	0	0
83	25	57	14	32	5	11
84 <sup>1/</sup>	15	36	14	33	13	31
Total	64	56	33	29	18	16

<sup>1/</sup> Series includes CP assignments only; other series include CP, L, and LCP assignments.

Table 3. Number and proportion of clones advanced from each smut disease reaction category.<sup>1/</sup>

Series	Clones advanced					
	Resistant		Intermediate		Susceptible	
	No.	%	No.	%	No.	%
1982-1983 Test						
75-79	3	43	3	33	3	23
80	3	50	1	100	5	33
81 <sup>2/</sup>	5	50	3	50	3	20
Total	11	48	7	41	11	26
1983-1984 Test						
77-80	3	60	3	43	2	22
81	10	62	3	75	1	20
82 <sup>2/</sup>	14	88	3	43	2	12
Total	27	73	9	50	5	25
1984-1985 Test						
79-81	7	58	3	50	0	0
82	11	73	5	50	3	18
83 <sup>2/</sup>	9	56	3	38	6	38
Total	27	63	11	46	9	25
1985-1986 Test						
79-82	16	67	1	20	0	0
83	15	60	7	50	0	0
84 <sup>2/</sup>	10	67	7	50	0	0
Total	41	64	15	45	0	0

<sup>1/</sup> Total clones tested and assigned to each smut disease reaction category is given in Table 2.

<sup>2/</sup> Series includes CP assignments only; other series include CP, L, and LCP assignments.

In the 1983-1984 test, the percentage of clones in the resistant and intermediate categories increased to 65% (Table 2); and a higher percentage of the resistant and intermediate clones were advanced to the next stage of testing (Table 3). The same percentage of clones were rated resistant or intermediate in the 1984-1985 test; however, among the more advanced clones (the 77-80 series in the 1983-1984 test and the 79-81 series in the 1984-1985 test) the proportion of resistant clones increased and the proportion of susceptible clones decreased from the former to the later test. The number and proportion of clones advanced from each reaction category was similar in the 1983-1984 and 1984-1985 tests (Table 3).

Over 50% of the clones tested in the 1985-1986 test were rated resistant to smut (Table 2). Among the more advanced clones (the 79-82 series), over 80% were classified resistant. These clones had been rated in two to three previous replicated tests. The 83-series clones, which had been in one replicated test, contained more resistant than intermediate and more intermediate than susceptible clones. Among the 84-series clones, the proportion rated in each reaction category was approximately equal. No susceptible clone was advanced from this test (Table 3).

Similar improvements in the proportion of resistant clones in the later stages of the selection program were found among the CP and the L and LCP clones.

#### DISCUSSION

Wu et al. (8) found the heritability of smut resistance to be high and predicted no difficulty in selecting smut-resistant, high-yielding clones. In the earliest smut resistance testing at Houma, the 1982-1983 test, resistant clones were identified among the unselected progeny (Table 2).

Clones were rarely dropped because of smut susceptibility alone in the initial replicated tests. This is reflected in the proportion of susceptible clones advanced after one replicated test (Table 4). As test results accumulated from two or more replicated tests, the selection pressure on clones for smut resistance increased (Table 3). It was not until the 1984-1985 test that any of the clones had been tested three times in replicated tests.

Table 4. Number of susceptible sugarcane clones advanced in the replicated tests.

Test	No. of times tested		
	1	2	3-4
1982-1983	26	-	-
1983-1984	12	21	-
1984-1985	38	18	0
1985-1986	0	0	0

It has been suggested that clones rated intermediate may be grown if not exposed to high inoculum pressure (1). Consequently, clones with high-yield potential that were rated intermediate have been advanced in the breeding and selection program.

The candidate cultivars tested between 1982 and 1986 are progeny of parental material unselected for smut resistance. Several workers have found resistant progeny from crosses of susceptible parents (6, 7, 8). Wu et al. (8) indicated that nearly 20% of the progeny from crosses between two highly susceptible parents were resistant to smut. They also found that the correlation between smut ratings and yield components was low. It is therefore not unexpected that clones with smut resistance and high yield potential were found among the progeny of unselected parents. The size of the breeding program, however, should be adjusted to compensate for the clones discarded because of susceptibility to smut to maintain the size of the selection program as it was before smut entered Louisiana (1).

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THE EFFECT OF PLANT GROWTH REGULATORS ON THE TILLERING OF BASIC  
CLONES OF FOUR SPECIES OF SACCHARUM<sup>1/</sup>

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ABSTRACT

The Louisiana sugarcane breeding program is currently using clones with high stalk populations as parents in an attempt to increase millable stalk number and consequently the yield of cane per unit area. This study was initiated to investigate the possible use of five synthetic growth regulators to increase millable stalk number.

Objectives of this study were to identify those plant growth regulators that cause the greatest increase in shoot number of 14 basic clones of four species of the genus Saccharum and, at the same time, to identify those genotypes that exhibit a high degree of response to certain growth regulators which have been proposed as tillering agents.

A series of three factorial experiments was conducted under controlled conditions in the greenhouse using 14 clones of the genus Saccharum along with five synthetic growth regulators.

Treatments were applied to the plants one month after germination. Shoot number and shoot height measurements were taken every two weeks, beginning two weeks after planting, for a period of eight weeks.

Plants treated with (2-chloroethyl) phosphonic acid (ethephon) produced the highest number of shoots and showed an increased growth rate. The (2-chloroethyl) trimethylammonium chloride (chlormequat) and poly [oxyethylene (dimethyliminio) ethylene (dimethyliminio) ethylene-dichloride] (bualta) treatments resulted in an increase in shoot production with no effect on growth rate. One-naphthaleneacetic acid (NAA) and 2,4-dichlorophenoxyacetic acid (2,4-D) increased shoot number but decreased plant growth.

Several clones of S. spontaneum and S. sinense responded to ethephon, chlormequat and bualta by increasing shoot number while showing no other effect on plant growth.

INTRODUCTION

Over the past 30 years, significant progress has been made in increasing the yield of sugar per hectare in Louisiana sugarcane through breeding (2). The yield of sugar per hectare has two major components: yield of sugarcane per hectare and yield of sugar per unit of sugarcane. The genetic progress made in increasing sugar per hectare has come mainly from increases in sugar per unit of sugarcane (2). However, little genetic progress has been made in increasing the yield of sugarcane per hectare in Louisiana.

Previous studies have shown a positive relationship between yield of sugarcane per hectare and number of millable stalks per hectare (6). Therefore, a means of increasing yield of sugarcane per hectare is to increase the number of millable stalks per hectare. A possible alternative to breeding and selection for increased millable stalks per hectare is to select for response to growth regulators that increase tillering. The promotion of tillering with growth regulators has been reported in barley by Leopold (5) and Jewiss (4). Nickell (9) cites Langer and Chang for work done on promoting tillering in wheat and rice, respectively.

Plant growth regulators have been used for over 20 years by the sugarcane industry to increase the recoverable sugar yield of sugarcane (8). The first commercial success was in the prevention of flowering, followed by the application of gibberellic acid for the increase of stalk elongation, which ultimately resulted in increased sugar production (10). Since 1972, two plant growth regulators have been registered in the United States as chemical ripeners (9). These compounds increase sugar yield through manipulation of crop maturity.

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This study was designed to identify those plant growth regulators that cause the greatest increase in shoot number without affecting the growth rate of the treated plants and to identify those clones of basic germplasm of several *Saccharum* species that exhibit the highest degree of response to certain plant growth regulators used as tillering agents.

#### MATERIALS AND METHODS

A series of three factorial experiments designed to measure the effects of five synthetic plant growth regulators on the tillering of four clones each of *Saccharum officinarum*, *S. robustum* and *S. spontaneum* and two clones of *S. sinense* were conducted under controlled conditions in the greenhouse between November 1983 and August 1984. Precautions were taken to avoid insect damage, breakage of shoots, chemical drift or any other outside source that might affect the results of these experiments.

Due to the genetic diversity of the 14 clones represented in these experiments, the length of time between the planting of bud cuttings and emergence of the first shoots varied greatly clone to clone. A preliminary study was conducted to determine the respective time to emergence of the first shoots for each clone (data not shown). Based on this study, (1) the planting dates of the clones in the subsequent experiments were staggered; the slower germinating clones were planted first and the faster ones last. This resulted in all clones germinating at approximately the same time. By following this planting procedure, it was possible to apply the growth regulator treatments to all clones at approximately the same stage of growth.

Experiment 1 was started in November 1983. Single bud cuttings of each clone were germinated with the 24 best plants of each clone selected for the experiment. Each of the five treatments plus control were replicated four times. The bud cuttings were germinated in styrofoam Todd Planter Trays<sup>2/</sup> with each tray having 18 cells. The cells were filled with Jiffy-Mix Plus<sup>2/</sup>. A single bud cutting was placed in each cell. The staggered planting date procedure was employed to synchronize germination. After germination, the clones were transplanted into 11.3 liter plastic pots containing a mixture of equal amounts of Commerce silt loam soil and peat moss. Initially, the pots were arranged in six groups of 56 to facilitate treatment application. Each group contained the 14 clones replicated four times. Each group was placed in a separate area of the greenhouse to avoid drift of the treatments during application. The clones then grew for one month, after which the chemical treatments were applied (Table 1). A back-pack type sprayer was used to apply the growth regulator mixtures to the foliage of the plants until run-off occurred. When the foliage dried, the pots were arranged into a completely randomized design in one area of the greenhouse.

Table 1. Plant growth regulators tested for ability to increase tillering in *Saccharum* species and their rates of application.

Common name	Chemical name	Rate
Untreated check		
NAA	1-napthaleneacetic acid	100ppm <sup>1/</sup>
2,4-D	2,4-dichlorophenoxyacetic acid	250ppm <sup>2/</sup>
Bualta	poly[oxyethylene(dimethyliminio)ethylene (dimethyliminio)ethylenedichlorida]	200ppm <sup>3/</sup>
Ethephone	(2-chloroethyl) phosphonic acid	500ppm <sup>1/</sup>
Chloromequat	(2-chloroethyl) trimethylammonium chloride	200ppm <sup>1/</sup>

- <sup>1/</sup> Kanwr, R. S. and K. Haimidder. 1977. Improving sprouting of stubble crops in low temperature areas. Proc. ISSCT 16:1325-1331.
- <sup>2/</sup> Nickell, L. G. 1982. Sugarcane, Plant Growth Regulating Chemicals. CRC Press, Boca Raton, FL. 7:186.
- <sup>3/</sup> Madrid, P. V. and E. L. Rosario. 1979. Chemicals on the tillering ability of variety. Phil 56-226. Sugarland 16(2):11-12.

<sup>2/</sup> Mention of a specific vendor does not constitute an endorsement of that vendor to the exclusion of all others that may also be suitable.

Experiment 2 was started in June of 1984. The bud cuttings used for this experiment were cut from stalks of the untreated check pots in Experiment 1. As in Experiment 1, twenty-four plants of each clone were selected. The planting and germination procedure was the same as that in Experiment 1. However, in Experiment 2, the entire experiment was conducted in styrofoam trays. The trays were arranged in six groups of 56 cells, or four trays per group at planting. Four replicates of the 14 clones were planted in each group where they remained until the treatments were applied. When the foliage dried, all 24 trays were placed in one group and the plants were rearranged within the cells of the group into a completely randomized design.

The third experiment also was initiated in June of 1984. All cane in the 11.3 liter containers of Experiment 1 was cut at the base of the stalks and the regrowth or "ratoon" crop formed the basis for Experiment 3. The pots were again placed into six groups as in Experiment 1 for one month after which the treatments were applied. After the foliage dried, the pots were rearranged into a completely randomized design in the greenhouse.

Variation of watering, fertilization, temperature, etc. within and between experiments was kept to a minimum. A strict watering and fertilization schedule was followed in all experiments. Temperature was thermostatically controlled in the greenhouse. One variation that was not controlled was the difference in day-length. The first experiment was performed during the winter when day-length ranged from 10 hrs. 10 min. to 10 hrs. 26 min. Experiment 2 and the ratoon experiment (Experiment 3) were carried out during the summer when day-length ranged from 13 hrs. 30 min. to 14 hrs. 8 min.

Measurements of height and total shoot number for individual plants of each clone in each pot were taken every two weeks for eight weeks from the time of germination until the rate of tillering had slowed or ceased. As a measurement of growth rate, plant height was calculated as difference in height (DHT) between day 14 and day 56. Plant height on any one day was measured as the length, in millimeters, between the soil line to the uppermost visible dewlap.

Shoot height, DHT and shoot number for each experiment were analyzed as a completely randomized design with a factorial arrangement of treatments using the general linear models (GLM) procedure (SAS)<sup>3/</sup>. An analysis of variance was calculated on the mean height and mean shoot number measurements taken at eight weeks on both untreated and treated clones and DHT measurements. Based on these analyses of variance, the means were separated by protected LSD tests.

The analyses of height and DHT measurements were used primarily to determine if there were effects on the growth rate of the clones by the treatments. Shoot count analysis was used to determine if there was a greater degree of tillering of the clones due to one or more of the treatments.

## RESULTS

### Plant cane results

Because of the similarity of results for mean shoot number from Experiments 1 and 2, these data were combined. Table 2 shows the mean shoot number for each clone as a result of each treatment. For SES 513, all growth regulators tested caused an increase in mean shoot number over the control. The ethephon treatment caused the greatest increase for SES 513, with NAA and chlormequat being similar. The 2,4-D treatment was lower than ethephon in mean shoot number but was not different from NAA, chlormequat and bualta.

The ethephon, chlormequat and bualta treatments caused a higher degree of tillering than the control for SES 577, Chunnee and Cristalina. However, the effects of 2,4-D and NAA on these clones were not different from the control. The clones SES 205-A and Cavengerie, when treated with ethephon, chlormequat and 2,4-D, produced higher mean shoot numbers than when left untreated. Bualta and NAA showed no effect on these clones. Mandalay responded to chlormequat, ethephon and NAA by producing more shoots under these treatments than when left untreated. Bualta and 2,4-D had no effect on this clone. Chlormequat and ethephon caused NG 77-132 to produce a higher mean number of shoots than the control. In this clone, the bualta, NAA and

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<sup>3/</sup> SAS Institute, Inc. SAS User's Guide: Statistics, 1982 Edition. Cary, NC: SAS Institute Inc., 1982. 584 pp.



2,4-D treatments had no effect. NG 77-136 and Louisiana Striped responded to only ethephon. All other treatments caused no change in shoot number from the control. Only chlormequat caused an increase in shoot number over the control in the clone NG 77-160. No other compound tested induced tillering in this clone. There was no response noted in IS 76-514 and NG 77-76 with all plants of NG 77-76 in the plant cane experiments producing only one shoot regardless of treatment.

Table 2. Effects of plant growth regulators on mean number of shoots produced by clones of different Saccharum species in plant cane.<sup>1/</sup>

Species	Cultivar	Control	Ethephon	Chlormequat	Bualta	2,4-D	NAA
<u>S. spontaneum</u>	SES 513	4.25	6.88	6.50	5.63	5.88	6.63
<u>S. spontaneum</u>	SES 577	4.00	5.75	5.38	4.88	4.62	4.25
<u>S. spontaneum</u>	SES 205-A	3.54	5.67	5.17	4.37	4.54	3.67
<u>S. spontaneum</u>	Mandalay	3.38	4.50	4.50	3.88	3.88	4.50
<u>S. sinense</u>	Chunnee	2.63	4.38	3.88	3.50	3.25	2.88
<u>S. sinense</u>	Katha	2.50	4.25	3.25	2.88	2.50	1.88
<u>S. robustum</u>	NG 77-132	2.00	4.00	4.25	2.50	2.25	2.38
<u>S. robustum</u>	NG 77-136	2.13	3.38	2.75	2.88	2.88	2.13
<u>S. robustum</u>	NG 77-160	1.00	1.75	2.50	1.38	1.13	1.38
<u>S. robustum</u>	NG 77-76	1.00	1.00	1.00	1.00	1.00	1.00
<u>S. officinarum</u>	Cavengerie	1.25	2.88	2.38	1.88	2.63	1.88
<u>S. officinarum</u>	Cristalina	1.13	2.63	2.88	2.00	1.13	1.38
<u>S. officinarum</u>	IS 76-514	1.63	2.25	1.38	1.63	1.00	1.00
<u>S. officinarum</u>	Louisiana Striped	1.00	2.00	1.38	1.38	1.38	1.13
Overall means		2.23	3.67	3.37	2.83	2.70	2.57

<sup>1/</sup> LSD @ .05 = 0.83

In Table 3, the increase in mean shoot number over the control resulting from treatment effects can be seen for each species. The increases are indicated by mean shoot number and percent increase over the control. Ethephon resulted in the highest average percent increase of all growth regulators tested having a range of 50.4% increase over the control in S. spontaneum to 95.2% increase in S. officinarum. Both ethephon and chlormequat were more effective than the other growth regulators in causing an increase in mean number of shoots in all species tested. Saccharum spontaneum responded to all treatments as indicated by the percent increase caused by each growth regulator over the control. Ethephon and chlormequat resulted in the highest percent increase over the check in S. sinense. Plants of S. sinense treated with NAA produced fewer shoots than the check. Clones of S. robustum and S. officinarum showed a higher degree of response when treated with ethephon and chlormequat than with any other growth regulator.

Table 3. The effects of plant growth regulator treatments on Saccharum species as indicated by mean shoot number and percent increase over the control in plant cane.

Species	Mean number of shoots of control	Increase in mean number of shoots over the control (%) <sup>1/</sup>				
		Ethephon	Chlormequat	Bualta	2,4-D	NAA
<u>S. spontaneum</u>	3.79	1.91(50.4)	1.60(42.2)	0.90(23.7)	0.94(24.8)	0.97(25.6)
<u>S. sinense</u>	2.57	1.75(68.1)	1.00(38.9)	0.62(24.1)	0.31(12.1)	-0.19(-7.0)
<u>S. robustum</u>	1.53	1.00(65.4)	1.10(71.9)	0.41(26.8)	0.29(19.0)	0.19(12.4)
<u>S. officinarum</u>	1.25	1.19(95.2)	0.76(60.8)	0.47(37.6)	0.29(21.6)	0.10( 8.0)
Overall % increase		(69.8)	(53.5)	(28.1)	(19.4)	( 9.8)

<sup>1/</sup> Numbers in parenthesis represent the increase, in percent, of mean shoot number when compared to the control.



Each growth regulator tested on plant cane resulted in an increase in mean shoot number over all clones. However, it was not known if this increase was at the expense of the growth rate of the plants. Therefore, the effects of the tillering agents on the growth rate (DHT) of the treated plants are also presented (Table 4). Due to significant interactions, the data for DHT for each experiment were analyzed separately. In Table 4, the effects of each treatment on the growth rate of each clone in Experiment 1 are presented. Ethephon caused a reduction in the growth rate of IS 76-514. In the clone Mandalay, bualta and 2,4-D resulted in a positive response as indicated by higher DHT measurements. Bualta reduced the growth rate of SES 513. No other effects on growth rate were observed in the first experiment.

Table 4. Effects of plant growth regulators on plant height (DHT)<sup>1/</sup> of 14 clones of Saccharum in Experiment 1 <sup>2/</sup>.

Species	Cultivar	Control	Ethephon	Chlormequat	Bualta	2,4-D	NAA
<u>S. spontaneum</u>	Mandalay	42.25	48.88	47.50	51.00	54.25	44.88
<u>S. spontaneum</u>	SES 513	21.50	19.75	19.63	12.75	20.75	19.50
<u>S. spontaneum</u>	SES 577	42.00	39.63	45.00	44.50	41.63	38.88
<u>S. spontaneum</u>	SES 205-A	13.50	14.33	16.50	17.50	16.83	13.17
<u>S. sinense</u>	Katha	18.75	19.00	18.75	19.38	18.50	21.25
<u>S. sinense</u>	Chunnee	18.38	20.00	18.75	17.75	17.75	18.13
<u>S. robustum</u>	NG 77-132	11.25	8.75	10.25	9.00	9.63	9.88
<u>S. robustum</u>	NG 77-160	10.00	8.63	9.38	10.13	7.88	9.63
<u>S. robustum</u>	NG 77-76	19.38	19.13	19.75	19.13	18.63	19.88
<u>S. robustum</u>	NG 77-136	9.38	10.63	9.13	10.13	12.00	11.75
<u>S. officinarum</u>	Cavengerie	10.13	9.00	10.38	8.88	9.25	8.88
<u>S. officinarum</u>	Christalina	12.38	11.50	10.75	10.88	11.50	10.75
<u>S. officinarum</u>	IS 76-514	10.88	6.00	8.38	6.75	9.88	7.13
<u>S. officinarum</u>	Louisiana Striped	11.75	12.13	12.38	11.13	10.75	10.00

<sup>1/</sup> DHT = height on day 14 subtracted from height on day 56 (mm)

<sup>2/</sup> LSD @ .05 = 4.82

Table 5 indicates the effects of treatment on the growth rates of the 14 clones in Experiment 2. Ethephon caused an increase in the growth rate of NG 77-132, NG 77-76, NG 77-160 and Chunnee. Mandalay responded negatively to ethephon treatment. The application of 2,4-D caused a reduction in the growth rates of Katha, NG 77-76, Mandalay, SES 513 and SES 577. Similar results occurred when Mandalay and SES 513 were treated with chlormequat; NAA also reduced the growth rate of Mandalay. No other effects were indicated in Experiment 2.

Table 5. Effects of plant growth regulators on plant height (DHT)<sup>1/</sup> of 14 clones of Saccharum in Experiment 2 <sup>2/</sup>.

Species	Cultivar	Control	Ethephon	Chlormequat	Bualta	2,4-D	NAA
<u>S. spontaneum</u>	Mandalay	73.63	62.38	63.63	68.00	48.88	49.18
<u>S. spontaneum</u>	SES 513	61.00	59.75	52.25	55.38	44.38	55.13
<u>S. spontaneum</u>	SES 577	54.88	57.25	54.38	51.00	25.50	55.10
<u>S. spontaneum</u>	SES 205-A	21.50	28.75	25.75	24.75	19.50	21.75
<u>S. sinense</u>	Katha	27.25	33.75	23.13	25.25	11.13	19.63
<u>S. sinense</u>	Chunnee	20.38	35.38	23.13	24.38	12.88	15.00
<u>S. robustum</u>	NG 77-132	9.00	23.63	9.38	7.00	5.25	5.25
<u>S. robustum</u>	NG 77-160	9.38	22.63	7.75	8.00	6.13	7.00
<u>S. robustum</u>	NG 77-76	18.63	28.50	14.63	15.00	7.25	11.88
<u>S. robustum</u>	NG 77-136	4.00	8.63	2.00	3.63	4.00	3.25
<u>S. officinarum</u>	Cavengerie	10.88	8.13	6.50	9.00	5.38	8.63
<u>S. officinarum</u>	Cristalina	8.75	13.13	8.38	8.38	4.88	4.88
<u>S. officinarum</u>	IS 76-514	6.13	9.88	4.00	4.38	5.00	4.75
<u>S. officinarum</u>	Louisiana Striped	5.38	4.88	2.25	2.50	2.25	1.88

<sup>1/</sup> DHT - height on day 14 subtracted from height on day 56 (mm)

<sup>2/</sup> LSD @ .05 = 7.97

## Ratoon results

The data of Experiment 3 were analyzed separately to determine the reactions of the 14 clones as a "ratoon crop" to the tillering agents.

In Table 6, the mean number of shoots produced by each clone as a result of the effects of each treatment on the ratoon crop are presented. There were seven clones in the ratoon experiment where no difference in mean shoot number occurred as a result of the treatments. These clones were Cristalina, IS 76-514, Cavengerie and Louisiana Striped of *S. officinarum* and NG 77-132, NG 77-160 and NG 77-76 of *S. robustum*. All treatments showed a higher mean shoot number than the control for the clones SES 513 and SES 577 of *S. spontaneum*. In the clone Mandalay, the untreated plants produced fewer shoots than treated plants in all the treatments except bualta, which was not different from the control. Ethephon caused the highest mean number of shoots to be produced in SES 205-A. The control plants produced fewer mean number of shoots than plants of all treatments except bualta, which was not different. The effects of chlormequat were not different from NAA or 2,4-D, but these three treatments resulted in a higher mean shoot number than the control for this clone. In Katha, chlormequat and NAA caused a higher number of shoots to be produced than control. The effects of all other regulators were not different from the control. Ethephon was the only treatment that caused an increase in mean shoot number over the control in Chunnee. In NG 77-136, the ethephon and chlormequat treatments resulted in higher mean shoot numbers produced than the control. All other treatments showed no effect on this clone. Ethephon and 2,4-D treated plants were higher in mean shoot number than those treated with chlormequat in Cavengerie, but neither was different from the control.

Table 6. Effects of plant growth regulators on mean number of shoots produced by clones of different *Saccharum* species in the ratoon experiment<sup>1/</sup>.

Species	Cultivar	Control	Ethephon	Chlormequat	Bualta	2,4-D	NAA
<i>S. spontaneum</i>	SES 513	26.50	58.75	56.50	59.75	60.25	56.25
<i>S. spontaneum</i>	SES 577	20.75	42.50	35.50	38.25	42.25	43.00
<i>S. spontaneum</i>	SES 205-A	18.50	57.75	41.75	27.00	30.75	44.50
<i>S. spontaneum</i>	Mandalay	25.50	38.00	40.75	30.75	38.00	38.00
<i>S. sinense</i>	Chunnee	26.00	38.00	34.00	23.50	29.50	26.50
<i>S. sinense</i>	Katha	25.25	32.00	38.75	26.75	30.00	36.25
<i>S. robustum</i>	NG 77-132	14.25	19.25	10.75	14.50	14.50	9.25
<i>S. robustum</i>	NG 77-136	12.75	31.00	23.25	12.25	12.00	15.50
<i>S. robustum</i>	NG 77-160	16.75	20.25	18.75	11.50	17.00	9.75
<i>S. robustum</i>	NG 77-76	4.50	4.75	4.50	7.00	2.50	4.50
<i>S. officinarum</i>	Cavengerie	11.50	18.00	6.75	11.50	22.75	11.00
<i>S. officinarum</i>	Cristalina	12.00	13.50	18.50	10.00	9.75	10.00
<i>S. officinarum</i>	IS 76-514	7.75	9.25	6.25	6.75	9.50	8.25
<i>S. officinarum</i>	Louisiana Striped	12.50	9.50	8.00	10.25	9.25	8.25
Overall means		16.75	28.04	24.57	20.70	23.43	22.93

<sup>1/</sup> LSD @ .05 = 11.28

Table 7 indicates the increase in mean shoot number caused by the treatments over control in each species. The data are presented as mean shoot number and percent increase over the control. *Saccharum spontaneum* showed a high level of response to all growth regulators tested. All growth regulators except bualta caused an increase in mean shoot number in *S. sinense*. Mean stalk number for the ethephon and chlormequat treatments was greater than for the 2,4-D and NAA treatments. *Saccharum robustum* responded positively to ethephon and chlormequat with all other treatments producing negative effects. In *S. officinarum*, ethephon and 2,4-D were the only growth regulators that caused an increase in shoot number. Three of four *S. officinarum* clones responded to ethephon in plant cane, but all were nonresponsive to all growth regulators in the ratoon experiment. NG 77-76 and IS 76-514 did not respond to any chemical in either experiment. Ethephon was the only growth regulator that resulted in an increase in shoot production across all species. Therefore, it had the highest percent increase when averaged over all species. Chlormequat also showed an increase when averaged over all species; however, *S. officinarum* did not respond. Bualta decreased shoot formation in all species except *S. spontaneum*. As in the plant cane experiments, height measurements were taken in the ratoon experiment every two weeks starting two weeks after planting.

Table 7. Effects of plant growth regulator treatments on Saccharum species as indicated by mean shoot number and percent increase over the control in the ratoon experiment.

Species	Mean number of shoots of control	Increase in mean number of shoots over the control (%) <sup>1/</sup>				
		Ethephon	Chlormequat	Bualta	2,4-D	NAA
<u>S. spontaneum</u>	22.8	26.4(115.9)	20.8( 91.3)	17.8( 78.1)	20.0( 87.7)	22.6( 99.2)
<u>S. sinense</u>	25.6	9.4( 36.6)	10.8( 41.9)	-0.5( -2.0)	4.1( 16.1)	5.8( 22.4)
<u>S. robustum</u>	12.1	6.8( 56.0)	2.3( 18.7)	-0.8( -7.0)	-0.6( -5.0)	-2.3(-20.2)
<u>S. officinarum</u>	10.9	1.6( 14.8)	-1.1(-10.7)	-1.3(-12.0)	1.9( 17.1)	-1.6(-15.3)
Overall % increase		( 55.8)	( 35.3)	( 14.3)	( 29.0)	( 21.5)

<sup>1/</sup> Numbers in parenthesis represent the increase in percent, of mean shoot number when compared to the control.

The clones of S. sinense and S. spontaneum again exhibited a higher growth rate than clones of S. robustum and S. officinarum, as shown in Table 8. No growth regulators affected the growth rates of Cristalina, Louisiana Striped and NG 77-160. In Mandalay and SES 513, all growth regulators caused a decrease in growth rate. Ethephon increased the growth rate over the control in IS 76-514, Chunnee, NG 77-132, NG 77-76, NG 77-136 and SES 205-A. NAA and 2,4-D caused a reduction in the growth rates of Katha and Chunnee. The growth rate of Cavengerie was reduced by ethephon, chlormequat and 2,4-D. Also, 2,4-D reduced the growth rate of NG 77-132, NG 77-76 and SES 577.

Table 8. Effects of plant growth regulators on plant height (DHT)<sup>1/</sup> of 14 clones of Saccharum in the ratoon experiment<sup>2/</sup>.

Species	Cultivar	Control	Ethephon	Chlormequat	Bualta	2,4-D	NAA
<u>S. spontaneum</u>	Mandalay	73.00	55.25	57.13	66.63	53.38	32.38
<u>S. spontaneum</u>	SES 513	62.63	52.13	47.63	44.63	48.75	54.25
<u>S. spontaneum</u>	SES 577	52.63	56.63	48.38	50.63	28.38	52.13
<u>S. spontaneum</u>	SES 205-A	22.50	30.00	25.13	25.88	20.00	23.63
<u>S. sinense</u>	Katha	26.25	28.50	22.50	22.63	10.50	20.13
<u>S. sinense</u>	Chunnee	23.00	28.75	19.25	26.63	13.15	14.88
<u>S. robustum</u>	NG 77-132	12.00	22.13	10.88	7.38	5.25	7.63
<u>S. robustum</u>	NG 77-160	6.00	10.25	5.13	1.38	3.75	2.25
<u>S. robustum</u>	NG 77-76	14.50	27.00	15.50	14.50	8.00	9.88
<u>S. robustum</u>	NG 77-136	11.00	21.75	7.62	7.50	6.88	7.38
<u>S. officinarum</u>	Cavengerie	13.88	8.63	6.88	9.25	6.00	9.88
<u>S. officinarum</u>	Cristalina	8.50	13.00	9.38	8.50	6.88	5.88
<u>S. officinarum</u>	IS 76-514	6.13	11.63	3.00	3.88	5.13	5.50
<u>S. officinarum</u>	Louisiana Striped	5.75	4.75	3.13	4.00	2.12	2.00

<sup>1/</sup> DHT = height on day 14 subtracted from height on day 56 (mm)

<sup>2/</sup> LSD @ .05 = 4.74

It became apparent during the course of this study that those species which exhibited a more vigorous growth habit also exhibited the greatest degree of response to growth regulator treatment. A correlation between the growth rates of each



untreated species and their respective mean shoot numbers averaged over all regulator treatments was calculated. Mean height was highly correlated to mean shoot number in both plant cane and ratoon experiments (Table 9).

Table 9. Correlation coefficients showing the relationship of mean shoot height of the untreated plants to mean number of shoots of the treated plants of 14 cultivars of Saccharum in the plant cane and ratoon experiments.

Plant cane experiments <sup>1/</sup>		Ratoon Experiment <sup>1/</sup>	
Mean shoot height vs. mean number of shoots	.99 **	Mean shoot height vs. mean number of shoots	.97 **

<sup>1/</sup> DF = 15

#### DISCUSSION

Clones of S. spontaneum produced the highest mean number of shoots of all clones tested in both the plant cane and ratoon experiments. Saccharum sinense clones produced a lower mean number of shoots than those clones of S. spontaneum but were higher in mean shoot number than clones of both S. robustum and S. officinarum. Most growth regulators tested caused the treated plants to produce more shoots than the control in the plant cane of most species. The only exception was NAA, which caused a negative response in S. sinense. In the ratoon experiment, S. sinense treated with bualta produced a lower mean shoot number than its control. Bualta, 2,4-D and NAA all caused a reduction in mean shoot number in S. robustum. S. officinarum responded negatively to chlormequat, bualta and NAA in the ratoon experiment. The ethephon treatment was the most effective in promoting tiller formation over all species in all experiments. These results are comparable to those of Takahashi (12), Eastwood (3) and Wong-Chong and Martin (13), all of whom obtained a high level of tillering through the use of ethephon. Chlormequat treated plants were lower in mean shoot number than the ethephon treated plants in all experiments. However, chlormequat was more effective than bualta, 2,4-D and NAA in all experiments.

In addition to enhancing shoot production, the ethephon treatment increased the growth rate of the plants when averaged over all species in the plant cane experiments and was not different from the control in the ratoon experiment. The growth rate of plants treated with chlormequat and bualta was no different from the growth rate of the untreated plants in all experiments. Plants treated with 2,4-D and NAA indicated a slower rate of growth than the untreated plants in both the plant cane and ratoon experiments.

Certain clones of S. spontaneum in combination with ethephon application produced the highest mean shoot number and mean DHT. A significant increase in mean number of shoots over the control without experiencing a decrease in the growth rate of the plants could also be obtained through certain combinations of clones of S. spontaneum or S. sinense with ethephon, chlormequat or bualta. Similar results were reported by Madrid and Rosario (7), who obtained a significant increase in tiller formation with ethephon and bualta and Pao (11) who stimulated tillering with ethephon and chlormequat.

Although Experiments 1 and 2 were conducted under different growing conditions, no evidence of a major differential clonal response to environment was indicated in the data for mean shoot number. This suggests that response to growth regulator treatment by the clones was expressed independently of environmental influences. However, highly significant differences in DHT data between experiments may be attributed to environmental conditions. There was little variation of growth rate among plants of Experiment 1, which were grown in large plastic pots of soil. The greater degree of variation in response of the plants to treatment in Experiment 2 could have been caused by the possible stressful conditions created by the restricted root zone of the styrofoam trays.

Because this study was conducted under greenhouse environment, these results may not be applicable under field conditions. Also, further research is needed to determine whether or not response to tillering agents is a heritable trait.



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# FERTILIZER NEEDS FOR SUCCESSION PLANTED SUGARCANE<sup>1,2/</sup>

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## ABSTRACT

Three experiments were conducted with sugarcane on Commerce silt loam to evaluate the fertilizer needs of succession cane in comparison with fallow planted cane and effects of carbofuran (Furadan®) on the yield response to applied fertilizers. The succession cane was planted immediately after harvesting a cane crop, and fallow cane was planted on the same date in a traditional manner after a fallow year. For succession planting, the land was subsoiled after destroying the old cane stubbles with a roto-tiller. Rates of nitrogen, phosphate and potash fertilizers and carbofuran applied in the fall at planting time and in the spring were tested in plant and stubble crops.

Significant yield increases were obtained primarily in stubble succession cane from N-P<sub>2</sub>O<sub>5</sub>-K<sub>2</sub>O fertilizer at rates up to 240-0-80 pounds/A applied in the spring and from rates of 90-90-90 pounds/A applied in the fall primarily in plant cane without carbofuran. A 10-pound/A rate of carbofuran applied in the fall and spring increased yield of succession cane mostly in plant cane without fall applied fertilizer. Although carbofuran increased yield, it apparently did not increase the yield response to applied fertilizers.

The fertilizer needs for succession cane on Commerce soil were higher than that recommended for fallow planted cane. Succession cane produced yields comparable to fallow cane with subsoiling and optimum fertilization at planting time and in the spring of each crop year.

## INTRODUCTION

Sugarcane in Louisiana is normally monocultured with planting in early fall on fallow land following a 3-year crop cycle. It is traditional to leave the land fallow for one year between crop cycles to control weeds, prepare land for planting and avoid replanting during the harvest season due to labor, weather and equipment limitations. However, the practice of having unproductive fallow land each year is costly and less important now with the use of better herbicides and precision leveled land. Planting sugarcane in succession or immediately after harvesting a crop is a common practice in other countries. Succession planting could become feasible early in the harvest season in Louisiana on well drained sandy soils with the present use of more efficient 3-row equipment, mechanical planters and 2-row cane harvesters.

Previous work has indicated that succession cane generally produces less yield than fallow planted cane, possibly due to a decrease in available soil nutrients and an increase in nematode population in the soil during a crop cycle (2, 4). Since succession planting is not normally practiced in this state, information on the nutritional needs of succession sugarcane is not available.

This study was made to evaluate the fertilizer needs of succession cane in comparison with fallow planted cane, and the effects of carbofuran (Furadan®) on the yield response to applied fertilizers.

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## MATERIALS AND METHODS

Three fertilizer experiments were conducted with sugarcane on Commerce silt loam soil at different locations on the St. Gabriel Research Station in St. Gabriel, Louisiana. The types of planting, crop years, cane varieties and soil test analysis for each location are shown in Table 1. Fertilizer rates were tested in succession and fallow planted cane in two of the experiments, and fertilizer and carbofuran rates were tested in succession cane in one experiment. The experiments were conducted with commercial varieties of cane in plant and stubble crops.

Table 1. The year, type planting, cane crop and variety, and soil analysis for the three fertilizer experiments with sugarcane on Commerce silt loam soil at the St. Gabriel Research Station.

	Experiment number		
	1	2	3
Year conducted	1983-85	1984-85	1985-86
Type planting	Succession Fallow	Succession Fallow	Succession
Cane crop	Plant cane 1st stubble 2nd stubble	Plant cane 1st stubble	Plant cane 1st stubble
Cane variety	CP 65-357 CP 72-370	CP 74-383	CP 70-321
<u>Soil test analysis</u>			
K, ppm	87	79	117
Ca, ppm	1621	2274	2036
Mg, ppm	263	389	360
P, ppm	166	200	160
Organic Matter, %	1.07	1.16	0.99
pH	6.3	7.6	6.2

The soil analysis was made on a composite sample from each location according to soil testing methods used in Louisiana (1). The extractable K and organic matter in the soil were relatively low, and extractable soil P was in a medium range at each location. The extractable calcium and magnesium and the soil pH were at adequate levels.

Experiment 1 was conducted in plant cane, first stubble and second stubble cane crops with varieties CP 65-357 and CP 72-370 in 1983-85. The fertilizer treatments consisted of 80, 160 and 240 pounds of N and 60, 120 and 180 pounds of potash per acre in plant cane and 120, 240 and 360 pounds of N and 80, 160 and 240 pounds of potash per acre in the stubble cane. The treatment combinations were applied to succession and fallow planted cane of each variety during the spring of each crop year.

Experiment 2 consisted of testing rates of fertilizers applied in the fall at planting time and during the following spring in succession and fallow planted cane. The test was made in plant cane and first stubble crops in 1984-85. The N-P<sub>2</sub>O<sub>5</sub>-K<sub>2</sub>O treatments in pounds per acre were a fall application of 90-90-90 fertilizer and spring applications of 120-0-80 and 240-0-160 fertilizers with each type of planting. The 120-0-80 fertilizer is normally recommended for a plant cane crop in fallow planted cane for this soil type.

Experiment 3 consisted of testing rates of fertilizers and carbofuran applied in the fall and spring in only succession planted cane. The test was conducted in plant cane and first stubble crops in 1985-86. The N-P<sub>2</sub>O<sub>5</sub>-K<sub>2</sub>O treatments in pounds per acre were a fall application of a 90-90-90 fertilizer and spring applications of 120-0-80 and 240-0-160 fertilizers in each crop year. Each fertilizer combination was tested with and without a 10-pound per acre rate of 15% carbofuran (Furadan®) applied in the fall and spring.

In each experiment, the fall treatments were applied in the planting furrow during September or October, and the spring treatments were applied in the off-bar furrow during the following April of each crop year. The plots were three rows wide and ranged in length from 50 to 75 feet. The treatments were arranged in a randomized factorial design with three replications.

The fallow cane was planted in a normal manner after a fallow year in a cane cycle. The succession cane was planted immediately after harvesting a second stubble cane crop. For succession planting, the existing rows were roto-tilled to destroy the old cane stubbles, subsoiled with a vertical mulcher subsoiler (3), rebuilt with disk choppers and furrowed for planting. The cane in both types of planting was planted on the same date in late October, and recommended cultural practices were used during the growing season.

The cane was cut with a soldier type harvester at a normal time in each crop year, and the yields were measured by weighing the millable cane stalks on each plot using tractor-mounted scales. Sugar yields were derived from refractometer and polariscope readings of the cane juice in a 10-stalk sample from each plot. The data from each experiment were analyzed statistically using a standard procedure for analysis of variance.

## RESULTS AND DISCUSSION

### Experiment 1

Effects of fertilizer treatments applied in the spring on the yield of sugarcane in Experiment 1 are reported in Table 2. The effects were similar with the two cane varieties in the test; therefore, the results are shown as an average of varieties during a 3-year cane cycle. Increases in cane yield due to the fertilizer treatments were significant in plant cane and in the 3-year crop average in succession, but not in fallow cane. The 240-0-180 fertilizer produced more cane yield than the 80-0-60 fertilizer in succession cane.

Table 2. Effect of rates of fertilizers on the yield of sugarcane planted in succession and after a fallow year on Commerce silt loam soil in Experiment 1.

Fertilizer applied N-P <sub>2</sub> O <sub>5</sub> -K <sub>2</sub> O <sup>1/</sup>	Yield of cane and sugar <sup>2/</sup>							
	Plant cane-83		1st stubble-84		2nd stubble-85		3-crop average	
	Cane	Sugar	Cane	Sugar	Cane	Sugar	Cane	Sugar
1b/A	T/A	1b/A	T/A	1b/A	T/A	1b/A	T/A	1b/A
Succession planted								
N <sub>1</sub> -0-K <sub>1</sub>	22.3	4012	26.7	5059	25.1	4885	24.7	4652
N <sub>2</sub> -0-K <sub>2</sub>	23.1	4082	27.3	4982	26.4	4706	25.6	4590
N <sub>3</sub> -0-K <sub>3</sub>	25.0	4451	29.7	5422	27.1	4723	27.3	4865
Succession ave.	23.5	4182	27.9	5154	26.2	4772	25.9	4703
Fallow planted								
N <sub>1</sub> -0-K <sub>1</sub>	25.9	4447	29.6	5169	23.7	4256	26.4	4624
N <sub>2</sub> -0-K <sub>2</sub>	28.3	4765	29.7	5135	25.1	4280	27.7	4727
N <sub>3</sub> -0-K <sub>3</sub>	27.7	4786	28.0	5229	25.4	4391	27.0	4802
Fallow ave.	27.3	4666	29.1	5177	24.7	4309	27.0	4718
HSD 5% treat.	2.7	651	NS	NS	NS	NS	1.8	NS
HSD 5% ave.	1.0	250	1.3	NS	1.4	330	0.7	NS
Mean fertilizer effect								
N <sub>1</sub> -0-K <sub>1</sub>	24.1	4230	28.1	5114	24.4	4571		
N <sub>2</sub> -0-K <sub>2</sub>	25.7	4424	28.5	5058	25.7	4493		
N <sub>3</sub> -0-K <sub>3</sub>	26.4	4619	28.8	5325	26.3	4557		
HSD 5% Mean	1.5	371	NS	NS	NS	NS		

<sup>1/</sup> N<sub>1</sub>, N<sub>2</sub>, N<sub>3</sub> rates were 80, 160, 240 in plant cane and 120, 240, 360 in stubble.  
K<sub>1</sub>, K<sub>2</sub>, K<sub>3</sub> rates were 60, 120, 180 in plant cane and 80, 160, 240 in stubble.

<sup>2/</sup> Average yield of varieties CP 65-357 and CP 72-370.



The mean effects of the fertilizer treatments indicated that the 160-0-120 and 240-0-180 fertilizers produced significantly more yield of plant cane than the 80-0-60 fertilizer. The mean yield increases due to fertilizer were not significant in first stubble cane and approached significance in second stubble cane. Generally, the increases were smaller in sugar than cane yield, apparently due to a lower percent sucrose in higher tonnage cane.

There was a significant interaction in yield between crop year and type of planting. The succession cane produced less yield in plant and first stubble crops but more yield in the second stubble crop than the fallow cane. The average sugar yields for the crop cycle were similar for both types of planting, especially with the highest fertilizer rate.

## Experiment 2

The results from fertilizer treatments applied in the fall and spring on yield of sugarcane during a 2-year crop cycle in Experiment 2 are reported in Table 3. Increases in cane yield due to fertilizer treatments approached significance in plant cane and were significant in first stubble cane and in the 2-year average with both types of planting.

Table 3. Effect of fall and spring applications of fertilizers on the yields of sugarcane planted in succession and after a fallow year on Commerce silt loam soil in Experiment 2.

Fertilizer applied N-P <sub>2</sub> O <sub>5</sub> -K <sub>2</sub> O		Yield of cane and sugar <sup>1/</sup>					
		Plant cane-84		1st stubble-85		2-crop average	
Fall	Spring	Cane	Sugar	Cane	Sugar	Cane	Sugar
lb/A	lb/A	T/A	lb/A	T/A	lb/A	T/A	lb/A
Succession planted							
0-0-0	120-0-80	31.5	5506	33.8	5572	32.7	5539
0-0-0	240-0-160	31.7	5111	37.6	6548	34.7	5830
90-90-90	120-0-80	34.2	5902	33.6	5923	33.9	5913
90-90-90	240-0-160	35.1	5843	36.2	6039	35.7	5941
Succession ave.		33.1	5591	35.3	6021	34.3	5806
Fallow planted							
0-0-0	120-0-80	36.0	6047	33.7	6265	34.9	6156
0-0-0	240-0-160	37.5	6475	31.5	5836	34.5	6156
90-90-90	120-0-80	37.7	6663	34.2	6471	36.0	6567
90-90-90	240-0-160	39.4	6901	35.9	6080	37.7	6491
Fallow ave.		37.7	6522	33.8	6183	35.8	6343
HSD 5% treatment		3.7	1565	2.5	NS	2.1	840
Mean fertilizer effect							
0-0-0	-	34.2	5785	34.2	6056		
90-90-90	-	36.6	6327	35.0	6128		
-	120-0-80	34.8	6029	33.8	6058		
-	240-0-160	35.9	6083	35.3	6126		
HSD 5% Average and Mean		1.1	475	0.8	NS		

<sup>1/</sup> Yield of variety CP 74-383.

The mean effects of fertilizer treatments indicated that the 90-90-90 fertilizer applied in the fall at planting significantly increased the cane and sugar yields in plant cane, especially in succession cane. Also, the 240-0-160 fertilizer applied in the spring increased cane yield over the 120-0-80 in plant cane. In stubble cane, there was an interaction in yield between fertilizer treatment and type of planting. The stubble yield increases were more pronounced from the fall fertilizer in fallow than succession cane and more from the spring fertilizer in succession than fallow cane.

As in Experiment 1, succession cane produced less cane and sugar yields in plant cane, but more cane yield in first stubble cane than the fallow planted cane. The average sugar yields produced during the 2-year crop cycle was slightly less in succession than fallow cane with each fertilizer treatment.

### Experiment 3

Effects of fertilizer and carbofuran treatments applied in the fall and spring on the yield of succession cane during a 2-year crop cycle in Experiment 3 are reported in Table 4. Increases in cane yields due to fertilizer treatments approached significance in stubble cane and were significant in plant cane and the 2-crop average without carbofuran. The yield responses to fertilizer were small in plant cane and negative in stubble cane with carbofuran.

Table 4. Effect of fall and spring applications of fertilizers and carbofuran on the yields of sugarcane planted in succession on Commerce silt loam soil in Experiment 3.

Fertilizer applied N-P <sub>2</sub> O <sub>5</sub> -K <sub>2</sub> O		Yield of cane and sugar from succession planting <sup>1/</sup>					
Fall	Spring	Plant cane-85		1st stubble-86		2-crop average	
lb/A	lb/A	Cane	Sugar	Cane	Sugar	Cane	Sugar
		T/A	lb/A	T/A	lb/A	T/A	lb/A
Carbofuran - check							
0-0-0	120-0-80	32.2	5956	40.9	8505	36.6	7231
0-0-0	240-0-160	32.9	5944	42.4	8370	37.7	7157
90-90-90	120-0-80	38.4	7467	40.0	8032	39.2	7750
90-90-90	240-0-160	36.8	7212	42.0	8136	39.4	7674
Check ave.		35.1	6645	41.3	8261	38.2	7453
Carbofuran - 10 lb/A							
0-0-0	120-0-80	39.4	7196	44.2	9061	41.8	8129
0-0-0	240-0-160	39.7	7562	44.7	8972	42.2	8267
90-90-90	120-0-80	39.5	7382	39.6	8244	39.6	7813
90-90-90	240-0-160	39.0	7321	40.5	8130	39.8	7726
Carbofuran ave.		39.3	7365	42.3	8602	40.9	7984
HSD 5% treatment		3.4	1288	2.9	917	2.3	707
Mean fertilizer effect							
0-0-0	-	36.1	6664	43.0	8727		
90-90-90	-	38.4	7346	40.5	8136		
-	120-0-80	37.4	7000	41.1	8461		
-	240-0-160	37.1	7010	42.4	8402		
HSD 5% Average and Mean		1.0	391	0.9	279		

<sup>1/</sup> Yield of variety CP 70-321.

The mean effects of the fertilizer treatments indicated that the 90-90-90 fertilizer applied at planting increased the cane and sugar yields in plant cane, principally without carbofuran, but not in stubble cane. The mean effect of 240-0-160 fertilizer applied in the spring was an increase in cane yield over the 120-0-80, principally in stubble cane without carbofuran, but not in plant cane. Apparently, the yield responses to the fertilizers were greater without carbofuran, the need for a fall application of fertilizer was greater in the plant cane, and the need for a high rate in spring was greater in the stubble cane of this succession cane.

As an average of fertilizer treatments, the carbofuran significantly increased the cane and sugar yields in each crop year, especially in plant cane without the fall applied fertilizer.

### SUMMARY

Commerce silt loam soil is relatively low in extractable soil K and organic matter and at a medium level in extractable P. Results indicated that the fertilizer needs for succession cane on this soil type are higher than the 80-0-80 and 160-0-80

fertilizers recommended for plant cane and stubble crops, respectively, in fallow planted cane. Yield increases with rates up to 240-0-180 applied in the spring were obtained in plant cane and especially in stubble crops of succession cane.

The application of a 90-90-90 fertilizer at planting time increased cane yield, especially in plant cane of succession cane without carbofuran. The carbofuran increased yield mostly in plant cane without fertilizer applied at planting time. Although the nematocide increased yield, it apparently did not increase the yield response to applied fertilizers.

Succession cane can produce total yields during a crop cycle comparable to fallow planted cane with subsoiling and optimum fertilization at planting time and in the spring of each crop year.

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# INVESTIGATION OF POTASSIUM NEEDS OF SUGARCANE IN TEXAS<sup>1/</sup>

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## ABSTRACT

Foliar K analysis of sugarcane from various fields has revealed levels of K which would be considered borderline for optimum production based on critical levels cited from other sugarcane growing areas. Since the soils of the Rio Grande Valley of Texas have inherently high levels of available K, the low K levels in leaf and sheath tissues were both puzzling and worrisome. In this study, the influence of K fertilization and the residual effects of N and P on cane and sugar yields was determined. Sugarcane cultivar CP 70-321 was fertilized in April 1986. Potassium as K-Mg was applied at rates of 0, 167 and 334 kg/ha. The K levels were superimposed on a former N-P experiment. There were 20 replications for each K level and 40 replications for the no K control. All plots received 200 kg/ha of N. Although leaf K concentration and DRIS indices of the previous crop indicated a need for K, the application of K fertilizer did not affect yields, the concentration of K in the leaf and sheath tissues or in the juice. In spite of the K application, the DRIS indice of 3-month-old cane indicated a deficiency of K relative to N and P. There was a yield response to residual N but not to residual P fertilizer. The cane which had not received N for the two previous years produced 87.3 Mg/ha, an 85% increase over the 47.2 Mg/ha yield during the second year where no N was applied. Apparently, N depressed fields may be resurrected if the stalk population is still present.

## INTRODUCTION

Tissue analyses of sugarcane from various fields in the lower Rio Grande Valley (LRGV) have sometimes revealed levels of potassium which would be considered borderline for optimum production based on the Diagnosis and Recommendation Integrated System (DRIS) or on critical levels cited from other cane-growing areas (3, 4, 5). DRIS indices from an extensive crop log sampling of sugarcane throughout the LRGV in the 1982-83 season suggested that K was the most deficient nutrient in 40% of the 3-month-old cane surveyed. Lack of yield response to applied K by sugarcane on LRGV soils has prevented the determination of the accuracy of the K diagnosis. Also the continually high levels of potash in molasses tend to support the belief that sugarcane in the LRGV has adequate K. The LRGV soils have inherently high levels of available potassium, therefore the lower potassium readings were both puzzling and worrisome.

The objectives of the test were to: 1) determine the effects of potassium on production and yield of cane; 2) observe the relationship of the various plant nutrients with one another and with yield; and 3) study the residual and/or additive effects of nitrogen and phosphorus from the previous two crops.

## MATERIALS AND METHODS

A K-rate study was begun in April 1986 on 3rd ratoon sugarcane (cultivar CP 70-321). The experiment was located near Madero, Texas on a Reynosa silty clay loam (Fluventic Ustiochrepts). The study was superimposed on a former nitrogen-phosphorus experiment. Potassium (K) as granular K-Mag (22.3% K<sub>2</sub>O, 18.6% MgO and 22.7% S) was broadcast over the cane at rates of 0, 167 and 334 kg/ha. The relation between the K treatments and the former N treatments is shown in Table 1. There were a total of 80 plots arranged in eight replications in 1985. Each plot consisted of three or four 9 m long rows spaced 1.8 m apart. All plots in 1986 received 200 kg/ha of N in the form of urea (46-0-0) applied over the cane row. No phosphorus was applied in 1986, however, in 1984 and 1985 one-half of the N plots received 112 kg/ha of P. Forty plots received no additional fertilizer

<sup>1/</sup> Contribution of the Conservation and Production Systems Research Unit, ARS, USDA, Weslaco, Texas in cooperation with Rio Grande Valley Sugar Growers Inc., Santa Rosa, Texas.



(other than N). The remainder were divided with 20 plots receiving 167 kg/ha of K and 20 plots receiving 344 kg/ha of K. The treatments were applied in alternating tiers providing 20 replications for each K level and 40 replications for the no K control.

Table 1. Potassium fertilizer treatments in relation to former nitrogen treatments.

Potassium applied 1986	No. of plots	Nitrogen applied		
		1986	1985	1984
kg/ha		- - - - - kg/ha - - - - -		
0	4	200	0	0
0	4	200	90	90
0	4	200	180	180
0	4	200	270	270
0	4	200	360	360
Total	20			
167	4	200	0	0
167	4	200	90	90
167	4	200	180	180
167	4	200	270	270
167	4	200	360	360
Total	20			
0	4	200	0	0
0	4	200	0	90
0	4	200	0	180
0	4	200	0	270
0	4	200	0	360
Total	20			
334	4	200	0	0
334	4	200	0	90
334	4	200	0	180
334	4	200	0	270
334	4	200	0	360
Total	20			

Leaf blades and sheaths numbered 3 through 6 were collected from five stalks in each plot three times during the growing season. The sheaths were separated from the leaf blades at the dewlap, dried at 70°C for moisture determinations and analyzed for P and K. The middle third of the leaf blades with midribs removed was oven-dried and analyzed for N, P, K, Ca, and Mg.

All plots received approximately 100 cm of water applied in nine irrigations. Effective rainfall during the January through December growth period was 29.8 cm. A relatively mild and dry winter promoted slow but steady growth in January and February in sharp contrast to the two previous years when severe freeze-back of ratooning cane occurred.

The dry leaves of cane in the field were burned in December 1986. Two rows, 9 m long, were hand harvested from each plot. After weighing, a 15-stalk sample was randomly removed from the windrowed cane in each plot. Cuban mill juice samples were collected and analyzed. Analysis of variance and LSD was used to determine effects of residual fertilizer and K fertilization on yields, juice quality and mineral composition.

# RESULTS AND DISCUSSION

Table 2 summarizes cane and sugar yields by K treatments and also segregates the results by the 1984 and 1985 N treatments. The most obvious and outstanding statistic is the overall tonnage produced by the 200 kg/ha N application on plots previously depleted of this nutrient. Thirty-two plots which had not received nitrogen in 1985 averaged 52.6 Mg/ha in the 1985 harvest but rebounded to 91.4 Mg/ha in the 1986 harvest. This 38.8 Mg/ha increase is a gain of 74%. Another 32 plots which received N fertilizer every year averaged 98.7 Mg/ha, up 14.1 Mg/ha from their 84.6 average for 1985. The remaining 16 plots which had not received N for two years averaged 87.3 Mg/ha, an 85% increase over their 47.2 Mg/ha yield in 1985. Yield recovery of such magnitude as encountered in this experiment is encouraging as it means that nutrient depressed fields may be resurrected if the stalk population is still present and other factors are not limiting.

Table 2. Cane and sugar yields as affected by K fertilization and residual N.

Nitrogen applied			Yields of			
1984	1985	1986	Cane	Sugar	Cane	Sugar
kg/ha			Mg/ha			
			0 kg/ha K		167 kg/ha K	
0	0	200	83.9	10.7	90.1	11.1
90	90	200	93.9	11.9	104.2	12.2
180	180	200	88.1	10.6	96.0	11.1
270	270	200	106.1	13.0	96.8	11.7
360	360	200	100.5	12.0	104.0	12.2
			0 kg/ha K		334 kg/ha K	
0	0	200	90.6	11.0	84.6	10.3
90	0	200	93.5	11.8	83.4	10.3
180	0	200	94.5	11.3	76.1	8.5
270	0	200	92.8	11.4	90.6	11.2
360	0	200	104.1	11.6	95.9	11.4

Difference of  $\pm 6.2$  and  $\pm 7.0$  Mg/ha are significant at 5% level of probability for overall K and N mean cane yield, respectively.

There was a significant increase in yields from carryover N from the 270 and 360 kg N/ha applications in 1985 and 360 kg/ha rate in 1984. Residual N from the 1984 applications of N increased cane yields by 4.1 Mg/ha, whereas a yield increase of 11.4 Mg/ha was attributed to residual N from the 1984 and 1985 applications. In June, there were no significant differences in leaf N concentrations between plots that received N fertilizer every year (2.09%) and plots not fertilized for two years (2.09%) (Table 4). However, in July, residual N significantly affected the leaf N concentration. Leaves from cane not fertilized for two years contained 1.45% N and cane leaves from plots that received N every year contained 1.51% N. The 200 kg/ha rate of N applied in 1986 apparently was very close to the amount required to produce the maximum tonnage possible given the nonlimiting growth conditions that existed.

Phosphorus did not appear to be limiting growth. Tissue phosphorus values surpassed critical levels as given by Samuel (4) when sheath and leaf P averaged 0.133% and 0.255% respectively, in June. Corresponding values in July were 0.099% and 0.211%. There was no significant difference in P concentration between plots which had received 112 kg/ha of phosphate ( $P_2O_5$ ) each of the last two years (but not this year) and those having received no  $P_2O_5$  for three consecutive years. Residual and mineralizable P in the soil supplied sufficient amounts of this nutrient as they have done in the zero  $P_2O_5$  plots in the previous two croppings. As a consequence there was also no significant difference in tonnage for plots regardless of their previous  $P_2O_5$  fertilization.

The additions of 167 kg of K did not influence yields. However, the application of 334 kg K/ha was associated with a yield significantly lower than the 0 and 167 kg/ha K level yields. Mean yields were 94.8a, 98.2a and 86.1b Mg/ha, respectively, for the 0, 167 and 334 kg K/ha treatments. Different letters next to the values indicate the statistical separability of the respective treatments. Values with the same letter denotes a nonsignificant difference. Since the 334 kg treatment was superimposed on plots that were not fertilized in 1985, the low average yield in 1986 may reflect a loss of stand. The 167 kg K treatment was superimposed on plots that were fertilized in 1984 and 1985. Lack of response to K fertilizer was surprising since the mean K concentration of leaves in the previous crop (Table 3) were below the critical value of 1.0 - 1.2% (2, 3) and the DRIS indices suggested that K was relatively deficient with respect to the other nutrients. However, the tissue K values for the current crop were above the critical level (Table 4). Sheath K concentrations were 3.73, 3.88 and 3.77%, respectively, for the 0, 167 and 334 kg K/ha treatments in June. Corresponding values in July were 3.52, 3.61, and 3.61%. The critical sheath K level according to Clements (1) is 2.25%. The negative K indices in June suggest that K was out of balance with respect to N and P. The higher K concentrations in the current crop compared to the previous crop may reflect differences in early season temperatures and more extensive rooting of the 1986 crop. Higher temperatures would increase K availability and absorption by the plant roots (6).

Table 3. Mean effect of N fertilization on leaf mineral composition and DRIS indices.

N applied	Date	Leaf composition			DRIS indices			Order of requirement
		N	P	K	N	P	K	
kg/ha		- - - -	% - - - -	-				
0	5/23	1.33	0.24	0.97	-27.0	40.6	-13.6	N>K>P
225 <sup>1/</sup>	5/23	1.93	0.23	1.11	- 1.8	16.0	-14.2	K>N>P
LSD <sub>05</sub>		0.09	0.02	0.06				
0	7/2	1.49	0.23	0.83	- 9.8	33.2	-23.4	K>N>P
225	7/2	1.81	0.23	0.96	- 0.4	21.0	-20.6	K>N>P
LSD <sub>05</sub>		0.08	0.02	0.08				
0	8/23	1.27	0.22	0.93	-23.7	34.6	-10.9	N>K>P
225	8/23	1.39	0.22	1.01	-18.5	27.8	- 9.3	N>K>P
LSD <sub>05</sub>		0.11	0.01	0.06				

<sup>1/</sup> Means of N rates applied in 1985 - 90, 180, 270 and 360 kg/ha.

Table 4. Mean effect of K fertilization on leaf mineral composition and DRIS indices.

K applied	Date	Leaf composition			DRIS indices			Order of requirement
		N	P	K	N	P	K	
kg/ha		- - - -	% - - - -	-				
0	6/10	2.09	0.25	1.35	- 3.4	11.9	- 8.5	K>N>P
167		2.11	0.26	1.39	- 4.2	11.8	- 7.6	K>N>P
334		2.17	0.26	1.36	- 1.5	10.9	- 9.3	K>N>P
LSD <sub>05</sub>		0.07	0.02	0.05				
0	7/30	1.45	0.21	1.35	-20.2	14.4	5.8	N>K>P
167		1.51	0.22	1.33	-18.2	15.0	3.2	N>K>P
334		1.50	0.21	1.38	-19.7	13.9	5.8	N>K>P
LSD <sub>05</sub>		0.08	0.02	0.06				
0	10/29	1.23	0.21	1.04	-27.0	30.4	- 3.4	N>K>P
167		1.28	0.21	1.05	-24.2	28.2	- 4.1	N>K>P
334		1.25	0.21	1.08	-25.3	26.5	- 1.2	N>K>P
LSD <sub>05</sub>		0.06	0.02	0.04				

200 kg/ha N applied to all plots.

The differences in the foregoing K values are minor. Because moisture was adequate at all times and because the leaf N concentration at the June 10 sampling was over 2% for all treatments, it is clear that this combination would abet K uptake rather than limit it (6). The cane, however, took up what it needed and obviously did not become a "luxury feeder" of K. Other work has shown that the leaf and sheath K concentrations were significantly correlated with the sheath moisture and leaf N concentration (3). Yates (9) reported that on some soil types N fertilizer reduced the response to K, apparently because N increased the uptake of K.

Potassium applications did not significantly affect juice quality or the inorganic impurities (Table 5). Mean percentage pol values were 16.4, 15.9, and 16.0%, respectively, for the 0, 167, and 334 kg K/ha treatments. Corresponding purities were 90.5, 90.0, and 90.1%. Potassium (K) and chloride (Cl) were the major constituents of the ash in the cane juice. The juice concentrations of K and Cl were less than reported in other studies with cultivar CP 52-68 (7), but similar to the juice mineral content of cultivar CP 65-357 (8).

Table 5. Effect of K fertilizer and residual N on the juice mineral content.

N applied			Juice mineral composition - me/100 g					
1984	1985	1986	N	P	K	Ca	Mg	Cl
kg/ha								
			0					
0	0	200	9.5	4.3	40.3	5.1	9.1	21.5
90	90	200	8.9	4.2	41.6	4.8	9.0	22.9
180	180	200	9.8	4.6	44.2	5.2	9.7	25.1
270	270	200	10.3	4.1	44.1	4.9	9.3	25.2
360	360	200	9.5	4.3	45.0	4.9	9.3	25.5
			167 kg/ha					
0	0	200	9.2	4.5	41.6	4.6	8.9	22.7
90	90	200	11.4	5.0	47.1	6.0	9.4	26.5
180	180	200	11.9	5.2	50.1	5.5	9.7	27.8
270	270	200	11.0	4.9	45.4	5.0	8.5	25.1
360	360	200	8.7	4.4	50.2	5.0	8.2	26.1
			334 kg K/ha					
0	0	200	10.9	4.4	45.1	5.6	9.9	29.2
90	0	200	10.6	3.9	45.3	5.1	9.8	31.0
180	0	200	12.2	4.7	47.1	5.1	9.9	25.7
270	0	200	10.0	4.4	44.8	4.9	9.6	24.9
360	0	200	12.7	4.5	47.7	5.1	9.9	26.6

No significant differences.

The addition of 18.6% MgO in the K-Mag fertilizer did not affect Mg content of the leaf blades. Soil availability of Mg sufficed to provide the zero treatment plots with the same leaf % Mg (.163) as the average of the treated plots. The cane did not "luxury" feed on magnesium.

It appears that the DRIS indices were not very useful in predicting response to K or Mg. DRIS indices based on three ratios (N/P, N/K and K/P) indicated that K was the most deficient element. Whereas, DRIS indices based on ten ratios implied that Ca was the most deficient element, followed by Mg, K, N and P. However, no response was obtained when K and Mg were applied. The calcium index was misleading, as a Ca deficiency on a calcareous soil is unlikely. Mean leaf Ca and Mg concentrations of 0.319 and 0.163%, respectively, are above the critical levels (3, 4). The DRIS worked reasonably well with N. The DRIS N index and the percentage of N in the leaves decreased from June to October.

Other factors not being limiting, nitrogen was the primary grower-managed nutrient influencing cane yields. The addition of 200 kg/ha adequately restored formerly depleted soils and cane tonnage to near maximum production levels. Potassium fertilization at rates of 167 and 334 kg/ha did not promote additional tonnage, hence is deemed unnecessary in this soil type under present conditions.



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POSTEMERGENCE CONTROL OF SCOURINGRUSH (EQUISETUM HYEMALE)  
ON SUGARCANE DITCHBANKS IN SOUTH LOUISIANA

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ABSTRACT

Postemergence applications of triclopyr [(3,5,6-trichloro-2-pyrindyl) oxy] acetic acid} at 2.2, 4.5, and 6.7 kg/ha and chlorsulfuron {2-chloro-N-[[[4-methoxy-6-methyl-1,3,5-triazin-2-yl)amino] carbonyl] benzenesulfonamide} at 0.04, 0.07, and 0.14 kg/ha applied alone or in combination were evaluated for the control of dense stands of scouringrush (Equisetum hyemale L.) growing along drainage ditches of sugarcane (Saccharum interspecific hybrids) fields in South Louisiana. Triclopyr at 6.7 kg/ha provided acceptable (>70%) control of scouringrush five weeks after either a fall or summer treatment. Chlorsulfuron applied alone provided unacceptable control of scouringrush and failed to increase scouringrush control when applied in combination with triclopyr during the same rating period. Scouringrush densities, 11 weeks after the fall treatment, and biomass production, 14 weeks after the summer treatment were not reduced to acceptable levels with any of the treatments evaluated. Retreating plots to create fall + summer and summer + fall sequential treatments resulted in 80 to 91% scouringrush control 30 and 16 weeks after retreatment with triclopyr at 6.7 kg/ha. Control with chlorsulfuron continued to be unacceptable with chlorsulfuron contributing only a marginal, additive effect to combinations with triclopyr. Results suggest that sequential postemergence applications of triclopyr may be an effective alternative to the use of soil sterilants for selectively controlling scouringrush along sugarcane ditchbanks.

INTRODUCTION

Members of the horsetail family, Equisetaceae, are among the oldest species of vegetation dating back to the Carboniferous epoch (8). One of the members of this family is a problem on drainage ditches in sugarcane fields of southern Louisiana, where dense stands of this perennial evergreen often impede the flow of water. Several common names are used to identify this weed. Because of its high silica content, early settlers used the stems to scour pots, hence the name scouringrush (6). Others refer to the weed as horsetail because of its resemblance to hair on a horse's tail (1). In South Louisiana, it is referred to as poppinggrass because of the popping sound made when the internodes are pulled apart or when the vegetation is crushed by wheeled equipment.

Like all members of the genus Equisetum, herbicidal control is difficult because the plant's dense upright growth, rudimentary leaves, and waxy stem surface make herbicide wetting and retention difficult. In addition, the plant's extensive rhizome system, the weed's principal method of propagation, limits the effectiveness of many postemergence herbicides which must be translocated to the rhizomes to provide long-term control (3). Several postemergence herbicides, including amitrole (1H-1,2,4-triazol-3-amine) (3, 7), asulam {methyl [(4-aminophenyl)sulfonyl]carbamate} (3, 7); fosamine [ethyl hydrogen (aminocarbonyl)phosphonate] (3); glyphosate [N-(phosphonomethyl) glycine] (3, 5, 7); and picloram(4-amino-3,5,6-trichloro-2-pyridine-carboxylic acid) (7), have been found to provide only fair control of Equisetum. Coupland and Peabody (4) found that the amounts of  $^{14}\text{C}$  recovered from the roots and rhizomes following postemergence applications of amitrole, glyphosate, and fosamine to E. arvense were small in relation to the amounts applied because relatively large amounts of the absorbed  $^{14}\text{C}$  were exuded from roots into the soil. This would make it difficult for toxic concentrations of these herbicides to accumulate in the rhizome buds.

More successful control of Equisetum growing on ditchbanks and rights-of-way has been obtained through the use of high rates of residual herbicides that sterilize the soil (7, 8, 9). Generally, these treatments are nonselective, destroying above ground vegetation via contact postemergence activity and forming a chemical barrier in the soil to prevent the emergence of new shoots. The resulting "bare ditchbank" is then subject to erosion. In addition, crops such as sugarcane are often planted

within 1 to 2 m of drainage ditches. Drift of these herbicides during application, lateral migration of the herbicides in the soil from the target area, and/or dispersal of treated soil onto the cropped area during ditch cleaning can result in injury to the standing crop and subsequent ratoon crops.

Independent screening trials have been conducted to evaluate various foliarly applied herbicides for the selective control of scouringrush growing on sugarcane ditchbanks. The ester formulation of triclopyr and chlorsulfuron appeared to be the most promising treatments, providing good to excellent control of scouringrush and other annual and perennial broadleaf weeds difficult to control with 2,4-D (unpublished data). Triclopyr, a relatively fast acting postemergence herbicide, is currently being used in the western United States for the control of honey mesquite (*Prosopis glandulosa* Torr.) on rangelands (2). Chlorsulfuron has been shown to provide effective postemergence and preemergence control of *E. hyemale* at rates of 0.07 to 0.56 kg/ha (6, 8). Evaluations of various rates of these herbicides applied alone and in combination were continued with the objective of developing herbicide treatments that provide selective preemergence and postemergence control of scouringrush. This would reduce the need for multiple postemergence applications, decrease potential erosion problems encountered with non-selective herbicides, and offer sugarcane growers a selective management tool for the control of scouringrush on ditchbanks with a minimal risk of sugarcane injury.

#### MATERIALS AND METHODS

Initial herbicide treatments were applied to dense stands of scouringrush growing on sugarcane ditchbanks in Lafourche Parish on September 21, 1982 (fall treatment) and July 14, 1983 (summer treatment). For these studies, ditchbank refers to the dry uncultivated tops of ditches. Postemergence herbicide treatments were applied as broadcast, aqueous sprays at 561 l/ha using a tractor-mounted, roller pump-pressurized sprayer. At the time of the initial treatment, scouringrush stems were 150 (fall) and 137 (summer) cm tall and sporeheads were fully developed. Herbicide treatments contained 0.5% v/v noxynol (9 to 10 POE) [ $\alpha$ -(p-nonylphenyl)- $\omega$  hydroxypoly (oxyethylene)] surfactant.

Herbicides were reapplied to designated plots on July 12, 1983, (fall + summer sequential treatment) and October 21, 1983, (summer + fall sequential treatment) as described previously. At the time of retreatment, scouringrush stems in the untreated plots were 160 cm tall with fully developed sporeheads (July 12) or 127 cm tall with no visible sporeheads (October 21).

Scouringrush control following single applications was based on visual estimates of shoot injury five weeks after treatment (WAT) and on shoot densities 11 weeks after the fall treatment or biomass production 14 weeks after the summer treatment. Scouringrush density was determined from four randomly selected 0.25 m quadrants per plot, and biomass was determined by measuring the fresh weights of shoots harvested from four randomly selected 0.25 m quadrants per plot. Results from these samplings were expressed as a percent reduction from the untreated check. The effects of follow-up treatments were assessed visually in both studies on February 9, 1984, 30 and 16 weeks following the July 12, 1983, and October 21, 1983, retreatments, respectively.

The experimental design for both locations consisted of a randomized complete block with four replications per treatment. Experimental plots were 2.4 m wide by 6.1 m long. All data were subjected to factorial analysis and the least significant difference (LSD) test at the 0.05 level was used to determine significant treatment differences.

#### RESULTS AND DISCUSSION

An interaction between chlorsulfuron and triclopyr was not observed five weeks following initial fall (Table 1) or summer (Table 2) treatments. When averaged across the various triclopyr rates, chlorsulfuron provided only a 7 to 12 percent increase in control over triclopyr treated plots that received no chlorsulfuron (Tables 1 and 2). In plots receiving only chlorsulfuron, this injury was primarily manifested as a stunting of treated plants. Scouringrush injury with triclopyr was manifested as shoot necrosis five to seven days after treatment with necrosis increasing as the rate of triclopyr increased. By 5 WAT, acceptable (>70%) levels of scouringrush control were observed only where triclopyr was applied at the 6.7 kg/ha rate.



Table 1. Scouringrush control five weeks after a fall treatment of chlorsulfuron or triclopyr applied alone or tank mixed.<sup>1/</sup>

Triclopyr	Chlorsulfuron (kg/ha)				$\bar{X}$
	0	0.04	0.07	0.14	
(kg/ha)	- - - - - (% control) - - - - -				
0	0	10	10	14	8 D
2.2	36	32	43	51	40 C
4.5	60	62	73	69	66 B
6.7	66	83	76	76	75 A
$\bar{X}$	40 b	47 ab	50 a	52 a	

<sup>1/</sup> Means within columns (upper case) and between rows (lower case) followed by the same letter are not significantly different at the 0.05 level of probability according to the LSD test of significance.

Table 2. Scouringrush control five weeks after a summer treatment of chlorsulfuron or triclopyr applied alone or tank mixed.<sup>1/</sup>

Triclopyr	Chlorsulfuron (kg/ha)				$\bar{X}$
	0	0.04	0.07	0.14	
(kg/ha)	- - - - - (% control) - - - - -				
0	0	23	11	19	13 D
2.2	40	42	50	41	43 C
4.5	55	71	64	70	65 B
6.7	75	71	80	77	76 A
$\bar{X}$	42 b	52 a	51 a	52 a	

<sup>1/</sup> Means within columns (upper case) and between rows (lower case) followed by the same letter are not significantly different at the 0.05 level of probability according to the LSD test of significance.

An interaction between chlorsulfuron and triclopyr was also not detected as reductions in scouringrush densities or biomass production 11 and 14 weeks after the initial fall and summer herbicide application, respectively (Tables 3 and 4). This indicates that the response resulting from the postemergence activity of triclopyr and the preemergence plus postemergence activity of chlorsulfuron was neither antagonistic nor synergistic. Regrowth from rhizome buds occurred in the triclopyr treated plots, causing the degree of control to be reduced from that observed 5 WAT. Although control was reduced, plots receiving triclopyr had sparser stands of scouringrush with stunted shoots, especially at the 4.5 and 6.7 kg/ha rates. The scouringrush control attributed to chlorsulfuron 5 WAT was no longer evident at the later rating date. Although the 0.07 kg/ha rate was sufficient to provide good control of *E. hyemale* in the northern United States (7), rates greater than 0.14 kg/ha would be required to provide acceptable control of the dense stands of scouringrush encountered on ditchbanks in Louisiana as evidenced here and in other studies (6).

Visual ratings made 30 weeks after the summer retreatment of plots treated initially in the fall (fall + summer), also indicated no interaction between chlorsulfuron and triclopyr (Table 5). When averaged over all triclopyr rates, 42 percent scouringrush control was observed with fall + summer sequential treatments of triclopyr. This control was increased by 22 and 28 percent with the addition of chlorsulfuron at 0.07 and 0.14 kg/ha, respectively. Good (>80%) control of



scouringrush was observed in plots retreated with triclopyr at 6.7 kg/ha with an 11 to 12 percent increase in control being attributable to the inclusion of chlorosulfuron at the higher rates in the tank mixture. This increase in control was not significantly greater than the 80 percent control observed with triclopyr applied alone.

Table 3. Chlorsulfuron and triclopyr effects on scouringrush density 11 weeks after a fall treatment.<sup>1/</sup>

Triclopyr	Chlorsulfuron (kg/ha)				$\bar{X}$
	0	0.04	0.07	0.14	
(kg/ha)	- - - - - (% reduction) <sup>2/</sup> - - - - -				
0	0	34	24	30	22 B
2.2	22	32	30	27	28 B
4.5	48	52	56	48	51 A
6.7	57	52	65	63	59 A
$\bar{X}$	32 b	42 a	44 a	42 a	

<sup>1/</sup> Means within columns (upper case) and between rows (lower case) followed by the same letter are not significantly different at the 0.05 level of probability according to the LSD test of significance.

<sup>2/</sup> Scouringrush densities were determined from four, randomly-selected, 0.25 m<sup>2</sup> quadrants per plot.

Table 4. Chlorsulfuron and triclopyr effects on scouringrush biomass production 14 weeks after a summer treatment.<sup>1/</sup>

Triclopyr	Chlorsulfuron (kg/ha)				$\bar{X}$
	0	0.04	0.07	0.14	
(kg/ha)	- - - - - [Fresh wt. reduction (%)] <sup>2/</sup> - - - - -				
0	0	30	2	-9.5	6 B
2.2	10	17	14	18	15 B
4.5	38	40	44	35	39 A
6.7	44	33	42	38	39 A
$\bar{X}$	23 a	30 a	26 a	20 a	

<sup>1/</sup> Means within columns (upper case) and between rows (lower case) followed by the same letter are not significantly different at the 0.05 level of probability according to the LSU test of significance.

<sup>2/</sup> Scouringrush biomass was based on a fresh weight determination from four, randomly-selected, 0.25 m<sup>2</sup> quadrants per plot.

Similar responses were observed 16 weeks after a fall retreatment of plots treated initially in the summer, with the bulk of the control being attributable to triclopyr (Table 6).

Table 5. Scouringrush control 30 weeks after a fall + summer sequential treatment of chlorsulfuron or triclopyr applied alone or tank mixed.<sup>1/</sup>

Triclopyr	Chlorsulfuron (kg/ha)				$\bar{X}$
	0	0.04	0.07	0.14	
(kg/ha)	- - - - - (% control) - - - - -				
0	0	26	41	57	31 C
2.2	34	31	51	53	42 C
4.5	55	64	73	78	68 B
6.7	80	84	91	92	87 A
$\bar{X}$	42 b	51 b	64 a	70 a	

<sup>1/</sup> Means within columns (upper case) and between rows (lower case) followed by the same letter are not significantly different at the 0.05 level of probability according to the LSD test of significance.

Table 6. Scouringrush control 16 weeks after a summer + fall sequential treatment of chlorsulfuron or triclopyr applied alone or tank mixed.<sup>1/</sup>

Triclopyr	Chlorsulfuron (kg/ha)				$\bar{X}$
	0	0.04	0.07	0.14	
(kg/ha)	- - - - - (% control) - - - - -				
0	0	39	19	15	18 D
2.2	25	46	48	34	38 C
4.5	59	68	71	73	68 B
6.7	87	85	78	81	83 A
$\bar{X}$	43 c	60 a	54 ab	51 b	

<sup>1/</sup> Means within columns (upper case) and between rows (lower case) followed by the same letter are not significantly different at the 0.05 level of probability according to the LSD test of significance.

These results indicate that the use of postemergence applications of triclopyr applied to actively growing scouringrush would be an effective alternative to the use of soil sterilants as a means of selectively managing this weed along sugarcane ditchbanks. Multiple applications of triclopyr would be required to eliminate scouringrush, particularly where dense mature stands are present and thorough spray coverage is difficult. The dense upright growth, rudimentary leaves, waxy stem surface, and the extensive rhizome system, characteristic of the genus *Equisetum*, would make control with single applications of postemergence herbicides difficult (3). The initial concept that the addition of low rates of chlorsulfuron would enhance triclopyr's control of scouringrush by supplying preemergence activity and additional postemergence activity, did not materialize. This may be attributed to the fact that the upper story of the dense scouringrush stand intercepted much of the herbicide spray, preventing thorough wetting of emerged shoots and the soil surface - necessities for optimum preemergence and postemergence herbicidal activity.

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CLONAL REPEATABILITY OF THE STABILITY-VARIANCE  
STATISTIC IN SUGARCANE<sup>1/</sup>

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ABSTRACT

Clonal repeatability of Shukla's stability-variance statistics  $\sigma_i^2$  (stability variance of *i*th genotype) and  $s_i^2$  (stability variance following removal of non-additivity), was studied in the plant-cane and ratoon crops of the final two selection stages of the University of Florida and USDA sugarcane breeding program in Florida. Clonal repeatability of these statistics for three selection criteria: sugar concentration (SC), yield of cane per hectare (THC) and yield of sugar per hectare (THS) was generally low. Conscious selection for these statistics may improve the clonal repeatability. Clonal repeatability of mean THC and THS was low, but it was high for SC, although conscious selection was practiced for all three traits. Methods of using the stability-variance statistics across traits are suggested.

INTRODUCTION

Genotype x environment (GE) interactions are often encountered in replicated yield trials conducted across a range of environments. These interactions have been a continuing challenge to plant breeders. The results of two previous studies by Kang and Miller (7) and Kang *et al.* (8) showed that of three methods of partitioning the GE interaction into variance components assignable to each genotype or cultivar, the stability-variance statistics ( $\sigma_i^2$  and  $s_i^2$ ) developed by Shukla (12) would be more useful to plant breeders in partitioning the GE interaction than ecovalence (13) and Plaisted and Peterson's (11) method. Shukla's (12)  $\sigma_i^2$  statistic provides an unbiased estimate of stability variance of the *i*th genotype. Through an approximate F test, the significance of  $\sigma_i^2$  can be tested to determine whether or not a genotype was stable. Shukla's method can be extended to use a covariate

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covariates to remove its/their linear effect from genotype x environment (GE) interaction. The remainder of GE interaction variance can be assigned to each genotype ( $s_i^2$  statistic) and the significance of each component tested.

Kang and Miller (7) indicated that to be effective selection criteria,  $\sigma_i^2$  and  $s_i^2$  must be repeatable between successive selection stages in sugarcane (Saccharum spp.). If a trait is repeatable between selection stages, it indicates that improvement made in one selection stage can be carried over to the next selection stage (10). Repeatability of  $\sigma_i^2$  between sets of environments has been determined in oat (Avena sativa L.) (3) and in reed canarygrass (Phalaris arundinacea L.) (2). In both cases, the repeatability was low.

In vegetatively propagated crops such as sugarcane, repeatability of a trait between selection stages has been termed clonal repeatability (4, 10). Kang and Miller (7) suggested that clonal repeatability be determined between the final two selection stages of the University of Florida-USDA sugarcane breeding program. The purpose of this study was to determine clonal repeatability of the stability-variance parameters for three traits which are used as selection criteria for advancing clones from one stage to the next. The three traits included the yield of sugar per unit weight of cane (SC), yield of cane per hectare (THC) and yield of sugar per hectare (THS); selection is based on these three traits (9).

#### MATERIAL AND METHODS

Data were obtained for SC, THC, and THS on a check cultivar (CP 63-588) and ten experimental cultivars that were selected on the basis of their superior agronomic performance in the penultimate selection stage (stage 3) of the Florida sugarcane breeding program. These cultivars were from a total of 105 experimental cultivars. The 105 experimental cultivars plus the check were planted in a randomized complete-block design with two replications at four locations: New Farm, east of Canal Point, Florida; Gulf and Western Food Products Company at Okeelanta, Florida; University of Florida's Everglades Research and Education Center at Belle Glade, Florida; and Shawnee Farms near Clewiston, Florida. All locations except Shawnee Farms had predominantly muck (organic) soil. The Shawnee Farms had sandy-muck soil. In the fall of 1979, multiple bud setts of each cultivar were planted in plots 4.57 m long and spaced 1.5 m apart. Cultural practices such as fertilizing, cultivating, and insect-pest control were the same as used in the commercial field in which each test was located and varied across locations.

For the plant cane crop, the number of millable stalks per plot was recorded in August 1980. From each plot a 10-stalk sample per plot was cut in October 1980 and weighed. The THC was estimated using plot size, stalk number, and mean stalk weight (kg). The samples were milled, and the crusher juice was analyzed for Brix (percent soluble solids) and apparent sucrose. Sugar concentration (SC) in g kg<sup>-1</sup> was calculated by using Arceneaux's modification of the Winter-Carp-Geerlig formula (1) based on Brix and sucrose of crusher juice. The THS was determined by multiplying THC by SC and dividing by 1000. All plots were allowed to ratoon and data were obtained from the ratoon crop in 1981 as in the plant cane crops.

In the fall of 1981, the ten experimental cultivars selected from the previous selection stage (stage 3) and the commercial check, CP 63-588, were planted in a randomized, complete-block design with four replications at seven locations, four of which were the same or nearly the same as stage 3 locations. Each 4-row plot was 10.7 m long, and rows were spaced 1.5 m apart. In October 1982, a 10-stalk sample was taken from each plot of two replications at each location. The processing of samples and calculations of SC and THS were the same as for stage 3. The THC, however, was measured by weighing an entire plot at the time of final harvest, which occurred later between November 24, 1982, and April 4, 1983 (5). For the final harvest, cane leaves (or trash) were burned a day ahead of harvest. Cane was hand-cut and weighed with a tractor-mounted grab-loader and a scale (9). A sample of 15 stalks was randomly selected from each plot; each sample was processed in the same manner as reported for the early (October) samples. All plots were allowed to ratoon and data from the ratoon crop were obtained in 1983-84.

Stability-variance statistics,  $\sigma_i^2$  and  $s_i^2$  (measures of GE interaction), were calculated for each cultivar by using the computer program developed by Kang (6). Rank-correlation coefficients were determined between stage 3 and stage 4 stability parameters for each trait. Comparisons were made of the four common locations between stage 3 and stage 4, between the stage 3 locations and the seven stage 4 locations, and between the four stage 4 locations common to stage 3 locations and the seven stage 4 locations.

## RESULTS AND DISCUSSION

Rank-correlation coefficients between stage 3 and stage 4 parameters,  $\sigma_i^2$ ,  $s_i^2$  and  $\bar{x}$  for SC, THC and THS are presented in Table 1. The correlation coefficients

between selection stages are a measure of clonal repeatability of a parameter. The clonal repeatability of  $\sigma_i^2$  for four locations was low for SC and THS in both plant-cane and ratoon crops except THS in ratoon crop at final harvest wherein it was significant but negative (-0.67\*). Repeatability was significant and negative in both crops for THC indicating that for this trait without conscious selection for stability we are unable to select consistently stable cultivars in the two stages in either crop. When seven locations of stage 4 were included in the analysis, the clonal repeatability was non-significant for all three traits in both crops.

The use of a covariate (environmental index) removed heterogeneity from the GE interaction. The  $s_i^2$  parameter calculated from the remainder of the GE interaction variance was not repeatable between selection stages in either crop for any trait except that it was significant but negative (-0.70\*) in the ratoon crop for THC when four locations were compared.

Clonal repeatability of mean ( $\bar{x}$ ) of SC was generally significant and positive; however, it was not significant for THC or THS. This indicated that selection for SC between stages would be repeatable and effective, but we cannot predict the means of THC and THS in stage 4 from the means in stage 3, although conscious selection was practiced for the three traits in advancing clones between the two stages. One explanation for the poor clonal repeatability of THC might be that in stage 3, THC was calculated from stalk number, stalk weight, and plot size, whereas in stage 4, an entire plot was weighed at final harvest time. Kang *et al.* (9) reported a significant correlation coefficient of 0.64\*\* between THC calculated from weight of an entire plot and THC estimated from stalk counts, average stalk weight, and plot size. This relationship explained about 41% of the variation in the two traits. Therefore, about 50% of the variation was due to other factors. If THC were estimated in both stages, its clonal repeatability would have been expected to be higher.

Table 1 also contains rank-correlations between parameters calculated for four locations vs seven locations, and for seven locations vs seven locations for stage 4. The comparison  $\sigma_i^2$ -S4-7L, vs  $s_i^2$ -S4-7L had all positive correlation coefficients and most were significant. High correlations were expected here because rank correlations were not independent. One would expect even higher correlations between parameters for six locations vs seven locations.

Table 1. Rank-correlation coefficients between stage 3 and stage 4 parameters,  $\Lambda^2_{\sigma_i}$ ,  $\Lambda^2_{s_i}$ , and mean ( $\bar{x}$ ), for SC, THC and THS at four locations (4L) and seven locations (7L) in plant-cane (PC) and ratoon (RT) crops.

Parameters correlated	Crop	Selection criterion <sup>1/</sup>				
		SC (g kg <sup>-1</sup> )		THC (t ha <sup>-1</sup> )	THS (t ha <sup>-1</sup> )	
		PH <sup>2/</sup>	FH <sup>2/</sup>	FH	PH	FH
$\Lambda^2_{\sigma_i-S3}$ vs $\Lambda^2_{\sigma_i-S4-4L}$	PC	-0.25	0.19	-0.75**	-0.24	0.21
	RT	0.29	-0.25	-0.64*	-0.35	-0.67*
$\Lambda^2_{\sigma_i-S3}$ vs $\Lambda^2_{\sigma_i-S4-7L}$	PC	-0.46	0.19	-0.23	-0.01	-0.25
	RT	-0.32	-0.37	-0.57	-0.40	-0.12
$\Lambda^2_{\sigma_i-S4-4L}$ vs $\Lambda^2_{\sigma_i-S4-7L}$	PC	0.81**	0.27	0.57	0.54	0.45
	RT	0.38	0.88**	0.90**	0.89**	0.40
$\Lambda^2_{\sigma_i-S4-4L}$ vs $\Lambda^2_{s_i-S4-7L}$	PC	0.72*	0.55	0.80**	0.64*	0.80**
	RT	0.72*	0.94**	0.94**	0.77**	0.78**
$\Lambda^2_{\sigma_i-S4-7L}$ vs $\Lambda^2_{s_i-S4-7L}$	PC	0.95**	0.84**	0.93**	0.95**	0.95**
	RT	0.95**	0.97**	0.92**	0.82**	0.84**
$\Lambda^2_{s_i-S3}$ vs $\Lambda^2_{s_i-S4-4L}$	PC	-0.17	0.21	0.05	-0.14	-0.16
	RT	0.11	-0.08	-0.70*	-0.07	-0.02
$\Lambda^2_{s_i-S3}$ vs $\Lambda^2_{s_i-S4-7L}$	PC	-0.57	0.13	0.23	-0.17	-0.22
	RT	-0.22	-0.25	-0.56	-0.10	-0.25
$\Lambda^2_{s_i-S4-4L}$ vs $\Lambda^2_{s_i-S4-7L}$	PC	0.50	0.23	0.32	0.64*	0.56
	RT	0.50	0.84**	0.67*	0.72*	0.67*
$\Lambda_{\bar{x}-S3}$ vs $\Lambda_{\bar{x}-S4-4L}$	PC	0.83**	0.74**	0.06	-0.17	-0.28
	RT	0.54	0.48	0.19	0.08	0.05
$\Lambda_{\bar{x}-S3}$ vs $\Lambda_{\bar{x}-S4-7L}$	PC	0.85**	0.72*	0.12	0.36	0.09
	RT	0.65*	0.65*	0.13	0.05	0.05
$\Lambda_{\bar{x}-S4-4L}$ vs $\Lambda_{\bar{x}-S4-7L}$	PC	0.98**	0.94**	0.70*	0.68*	0.77**
	RT	0.87**	0.95**	0.97**	0.91**	0.98**

<sup>1/</sup> SC = sugar per unit weight of cane, THC = yield of cane per ha, and THS = yield of sugar per ha.

<sup>2/</sup> PH = preharvest, and FH = final harvest.

<sup>3/</sup> S3 = Stage 3, and S4 = Stage 4.

\*, \*\* Denote significance from zero at the 5% and 1% levels, respectively.

In the comparison  $\Lambda^2_{\sigma_i-S4-7L}$  vs  $\Lambda^2_{s_i-S4-7L}$ , all correlations were not only positive but also highly significant. It follows, therefore, that when comparisons were made between the same set of locations, given parameters were better correlated than when the comparison was between different number of locations. Correlation coefficients between  $\bar{x}$ -S4-4L and  $\bar{x}$ -S4-7L were significant for all three traits in both plant-cane and ratoon crops, and they were higher in the ratoon crop in most cases. The SC for seven locations can be easily predicted from SC for four locations since the correlation coefficients were very high and significant.



As a result of this study, it is proposed that a conscious selection for low stability variance be practiced to effect a desirable improvement in its clonal repeatability. One way of considering stability variance in advancing clones from one replicated stage to another might be by assigning ranks in descending order (the highest value is given a rank of 1) to clones relative to their stability variance for each of the three traits. The ranks may be summed across traits, and the clones with the highest sum be selected. Alternatively, significance of the stability variance can be determined as suggested by Kang and Miller (7) and the number of traits for which a clone was unstable used as a selection criterion.

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# HOT-WATER CURE OF SUGARCANE MOSAIC IN SUGARCANE STALKS IN LOUISIANA

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## ABSTRACT

Mosaic-infected stalks of three commercial sugarcane varieties, CP 65-357, CP 72-356, and CP 72-370, were serially treated with water at 55°C. The serial treatment consisted of immersions of 7.5 minutes on the first day, 40 minutes on the second, and 80 minutes on the third. The treated stalks were planted in the field, and the shoots growing from them were examined repeatedly to determine total shoot number and frequency of disease-free shoots. The level of survival in treated cane planted weekly between September 4 and October 1 was comparable to that of untreated cane. The level of disease control varied among and within varieties; the average disease control ranged from 42 to 73% in June following the fall plantings of eight successive experiments conducted a week apart.

## INTRODUCTION

Plants growing from seed cane heat-cured of sugarcane mosaic have been found to be healthy in all respects, both in the greenhouse (2) and in the field (Benda, unpublished). The plant cane and stubble from heat-cured seed cane have been used experimentally at Houma in certain field plantings when mosaic-free cane was required. Under conditions favoring spread of the sugarcane mosaic virus, the heat-cured cane will become infected like other healthy cane.

This paper describes the results obtained with a serial hot-water treatment to cure sugarcane stalks diseased with sugarcane mosaic, a treatment that is applicable under plantation conditions. In order to develop this treatment series, three problem areas had to be investigated involving the relationships associated with treatment schedules and cures, with heat resistance and heat adaptation, and with heat effects and the re-distribution of residual virus, and the results coordinated with the requirements of mechanical harvesting and cultural practices.

The minimum temperature required for disease cures depends in part on the duration of treatment and the sugarcane mosaic virus strain involved (2); for a given length of treatment, the temperature is lower for Strains H and I, the predominant strains in Louisiana, than it is for Strains A, B, or D. A method to estimate the equivalence of various temperature-duration combinations in their effects on cures and survival has been presented for sugarcane (6).

Hot-water treatments for sugarcane mosaic require combinations of temperatures and durations that, in unprepared cane, severely reduce survival. The capacity of cane to withstand heat is increased by various actions and precautions before, during, and after treatment (6) and by adapting the cane by one or more pretreatments at high temperatures (3, 6). Varietal differences in resistance to heat and age of cane affect the extent that heat adaptation increases survival. Heat adaptation is favored by ambient temperatures between 20°C and 30°C before, between, and after treatments; lower or higher ambient temperatures may affect survival adversely. Preliminary observations have indicated that the adverse interaction of unfavorable temperatures and serial treatments in relation to survival is complex and varies among varieties.

Not all virus may be inactivated in cane exposed to a serial heat-treatment (3), and the residual virus may re-establish a general infection of the treated cane. Conditions which favor such re-establishment have been studied indirectly in experiments involving the inoculation of heat-treated cane, recovery from infection, and virus spread within inoculated seed cane. Heat treatment of seed cane for the control of the ratoon stunting disease has been found to increase the susceptibility to sugarcane mosaic virus infection of shoots growing from the treated seed cane (7, 8). The proportion of infected seed cane after inoculation with the sugarcane mosaic virus may be greater in heat-treated than in untreated seed cane; the likelihood of such increase in infection rate appears to be a function of the severity of heat treatment (1). When sugarcane recovers from sugarcane mosaic virus infection, the plant becomes disease-free; there apparently is an intermediate stage

where virus is still present, and this residual virus may be inactive if the plant recovers, or it may re-establish itself in all or a part of the plant (4). The results from one variety/mosaic virus strain combination indicate that in single-node cuttings, the frequency of recovery may be reduced due to heat treatment (4); in cuttings of more than one node, the rate of recovery is reduced compared to one-node cuttings whether heat treated or not (5). This system suggests a greater susceptibility to residual virus in multinode cuttings. Furthermore, sugarcane mosaic virus can move freely in seed cane so that infection of one shoot may lead to the infection of all shoots of that seed cane (5).

Plantation practices impose their own requirements on heat-treatment procedures. The minimum length of stalk that can be handled efficiently by the current mechanical harvesters and loaders is 5-ft (1.5m), and this length includes many nodes. Whether a cut stalk has an intact terminal meristem within the minimum length depends on the harvest date of the seed cane and on the growth conditions of that year. Previous results have shown that cures in variety CP 72-356 are favored if the terminal meristem is intact, whereas in CP 65-357 cures are favored if the terminal meristem and the immature nodes are removed (Benda, unpublished).

Constraints on the length of the hot-water treatment season are imposed by the potential severity of Louisiana winters on survival. Experiments with field planting of seed cane treated at temperatures of 55°C or above have shown that treated cane planted in July, early August, or after September may in wet and cold autumns give poor stands the following year. Cane treated for mosaic control in August and the first week of September did not survive the unusually cold winter of 1984-1985 (Benda, unpublished).

Louisiana winters also decrease the proportion of symptom-free shoots among total shoots from seed cane hot-water treated for mosaic control. The differences in the proportion between autumn and spring have been noted in the years when the aboveground parts have been frozen back and also in the spring of 1983 after a winter when the minimum air temperature was -1°C and the leaves were not frozen (Benda, unpublished).

The varieties grown commercially change over the years. Varieties which are cured readily, like CP 52-68 and L 62-96, as well as those which are difficult to cure, like CP 67-412 and NCo 310, are no longer recommended for commercial use. Varieties intermediate in their response to hot-water treatment include the three most mosaic susceptible varieties currently recommended, CP 65-357, CP 72-356, and CP 72-370.

In order to evaluate the effect of hot-water treatment on survival and cure of these three varieties, a series of eight separate experiments conducted at weekly intervals were begun in August 1986.

#### MATERIALS AND METHODS

In each of eight separate experiments, 50 shoots of first-stubble cane were harvested by hand for each of four varieties. Three varieties, CP 65-357, CP 72-356, and CP 72-370, were taken from mosaic nurseries, and every shoot selected had mosaic symptoms at harvest. The fourth variety, CP 70-321, moderately resistant to mosaic infection and relatively susceptible to heat injury, was harvested from border rows planted with symptom-free cane, and although not every shoot was examined, the mosaic incidence appeared to be very low. The shoots were topped to give a 5-foot (1.5 m) length from the base at soil level to the young end, and the leaf sheaths were left to cover the buds. The canes of each variety were divided into ten bundles of five canes each, the bundles were tied with string, tagged, and stored outdoors, with half the bundles assigned to be hot-water treated, the other half to be left untreated.

The hot-water treatments, all at 55.0-55.3°C, were begun four to five days after harvest. The three treatments were given on successive days, the first, 7.5 minutes long, the second, 40 minutes, and the third, 80 minutes. After the third treatment, both the treated and the untreated cane were planted in the field, usually within a day except in the eighth experiment when rain delayed planting (Table 1).

Each of the eight experiments was planted according to a completely randomized block design for 40 plots, a block consisting of the four varieties serially treated and the four varieties not treated, the block replicated five times. The plot was



about 30 ft (10 m) long on one row, and the interrow distance was 5 ft, 10 in (1.75 m). The canes were planted in a line in a v-shaped furrow on raised rows and without any overlap. After planting, the canes were covered lightly with soil, and a preemergence herbicide was applied within three weeks. Subsequent operations, cultivation, fertilization, and spring herbicide application, followed plantation practice.

The first five experiments were planted in a silty loam, while the last three experiments were planted some eight miles away in a clay soil.

Counts of shoots with and without mosaic symptoms were begun in the fall when the new growth was large enough for symptoms to be distinguished. The first three experiments were counted in November, and the next three, in December 1986 (Table 1). The last two experiments did not reach sufficient size to be counted before the leaves were frozen back. All eight experiments were counted in April and again in June 1987 (Table 1).

Table 1. Dates of seed-cane harvest, treatment, planting, and counts of shoots for a series of eight experiments.

Expt.	Dates, 1986, of				Dates, 1987, of	
	Seed cane harvest	Hot-water treatment series	Field planting	Fall counts	April counts	June counts
1	8/21	8/25-27	8/27	11/13	4/30	6/10
2	8/29	9/2-4	9/4	11/13	4/29	6/10
3	9/3	9/8-10	9/11	11/13	4/29	6/29
4	9/11	9/15-17	9/18	12/3	4/29	6/29
5	9/18	9/22-24	9/25	12/4	4/29	6/29
6	9/25	9/29-10/1	10/1	12/5	4/30	6/23
7	10/2	10/6-8	10/8	---	4/30	6/24
8	10/10	10/14-16	10/20	---	4/30	6/24

As the experiments differed in the time of planting, in the source of cane from different nurseries, and in the location of planting, no attempt was made to combine the experiments. The data for shoot number were transformed using the square root of  $x + 0.5$ . The Duncan Multiple Range Test was applied to the transformed data to separate the means of shoot numbers for variety and treatment within an experiment.

Disease control for each treatment and variety in an experiment was calculated as the ratio ( $\times 100$ ) of the total number of shoots without symptoms divided by the total number of shoots.

## RESULTS

Shoot number varied among varieties and experiments and between hot-water treated and untreated cane (Table 2). The variation in shoot populations from untreated seed cane evident among varieties in the different experiments may have its origin, at least in part, in plant health. The greater shoot number in CP 70-321 may be related to the absence of mosaic; while the other three varieties were nearly completely infected with mosaic, CP 70-321 had less than 1% of its shoots with mosaic symptoms (data not shown). In Experiments 6 to 8, the untreated CP 65-357 had significantly fewer shoots than other untreated varieties (Table 2); the cane of CP 65-357 was from a source which had not been heat treated for the control of the ratoon stunting disease for many years, while most of the cane of the other varieties in these three experiments were stubble of direct heat-treated cane.

Hot-water treatment reduced shoot number in CP 70-321 and CP 72-370 compared to untreated cane in nearly all experiments. In CP 65-357 and CP 72-376, the effect varies among experiments, the results suggesting no strong trend favoring treated or untreated (Table 2).



Table 2. Mean number of shoots per plot in June, 1987, as a function of variety and treatment in experiments begun in successive weeks.

Expt.	CP 65-357		CP 72-356		CP 72-370		CP 70-321	
	HWT <sup>1/</sup>	N	HWT	N	HWT	N	HWT	N
1	101.4 ab <sup>2/</sup>	113.8 ab	88.6 bc	96.6 b	63.4 c	122.4 ab	98.2 b	136.6 a
2	57.6 b	133.8 a	152.8 a	164.4 a	62.2 b	125.2 a	58.2 b	142.8 a
3	97.8 ab	82.8 ab	104.8 a	90.4 ab	65.2 bc	93.4 ab	50.2 c	98.0 ab
4	87.6 a	56.4 bc	70.0 ab	44.0 cd	56.6 bc	57.0 bc	31.0 d	64.8 b
5	55.6 b	45.0 b	56.8 b	29.6 c	40.0 bc	56.6 b	81.8 a	78.0 a
6	90.2 a	45.8 c	105.2 a	75.2 ab	56.0 bc	75.4 ab	53.6 c	82.6 ab
7	69.2 ab	40.6 b	73.8 ab	77.2 a	17.2 c	93.2 a	59.0 ab	89.0 a
8	5.2 de	16.8 cd	24.0 bc	40.4 ab	5.6 de	48.2 ab	1.6 e	64.4 a
Avg.	70.6	66.9	84.5	77.2	45.8	83.9	54.2	94.5

<sup>1/</sup> HWT: serially hot-water treated; N: not heat treated.

<sup>2/</sup> Means followed by the same letter--read horizontally--are not significantly different at the 0.05 level of probability according to the Duncan Multiple Range test performed on transformed data ( $\sqrt{x + .5}$ ).

In Experiment 8, the shoot totals from the hot-water treated seed cane were less than from the untreated in all four varieties (Table 2). There were no shoots at all in June on 11 of the 20 plots planted with treated seed cane, namely, four plots each of CP 65-357 and CP 70-321, and three plots of CP 72-370, while all five plots of CP 72-356 had some shoots. Among the 20 plots planted with untreated seed cane, only a single plot of CP 65-357 was without any shoots. The planting in Experiment 8 had been delayed by rain, and the cane, treated and untreated, was exposed on the last six nights before planting to minimum air temperatures of 14, 11, 10, 8, 8 and 13°C. The only other experiment in which there were plots without any shoots were two of the five plots of CP 72-370 in Experiment 7 planted with heat-treated seed cane. In this experiment, the cane was exposed for one night to a minimum air temperature at 18°C. In the other six experiments, the minimum air temperature did not drop below 19°C, and generally was above 21°C.

The data for disease control by hot-water treatment are presented in Table 3. It is evident that there is a much higher proportion of shoots without mosaic symptoms in all three varieties in the counts of November and December than in April or June. Furthermore, there appears to be general agreement between the proportion of symptom-free shoots in April and June. The discrepancy between April and June data for CP 65-357 and CP 72-370 in Experiment 8 is associated with a small number of shoots and few plots with any shoots at all.

Table 3. The percentage (%) of symptom-free shoots from seed cane exposed to serial hot-water treatment as a function of variety and time of observation in experiments begun in successive weeks.

Expt.	CP 65-357			CP 72-356			CP 72-370		
	Fall 86	April 87	June 87	Fall 86	April 87	June 87	Fall 86	April 87	June 87
1	99	61	53	95	91	81	89	78	77
2	100	63	59	100	85	84	100	100	100
3	88	70	56	56	24	19	94	50	51
4	84	57	47	87	60	56	94	76	63
5	90	70	66	66	12	11	100	88	82
6	99	55	40	90	51	52	100	68	56
7	--	27	19	--	63	69	--	92	78
8	--	67 <sup>1/</sup>	0	--	27	36	--	50 <sup>1/</sup>	77
Avg.	93.4	58.7	42.5	82.3	51.6	51.0	96.2	75.3	73.0

<sup>1/</sup> Based on a total of 6 shoots.

It has not been possible to associate the poor control in CP 65-357 in Experiment 7 and in CP 72-356 in Experiments 3 and 5 (Table 3) with any modification in experimental procedure.

Only a few symptom-free shoots were observed in June in the plots planted with untreated seed cane of CP 65-357, CP 72-356, or CP 72-370 in the eight experiments. In 20 of the 24 variety-experiment combinations, there were no symptom-free shoots from untreated seed cane; the other four combinations included CP 72-370 with 11.7% of symptom-free shoots in Experiment 5 and less than 1% in Experiments 4 and 6, and CP 72-356 with 7.1% of symptom-free shoots in Experiment 4. Even in experiments where some shoots from untreated seed cane were symptom-free, the proportion of such shoots was less than from hot-water treated seed cane.

The role of aphids in transmitting sugarcane mosaic virus is difficult to estimate in field experiments because of the non-random pattern of spread and the differences among varieties in susceptibility to natural spread. Counts of shoots with and without mosaic symptoms in plots of CP 70-321 indicate that the level of spread was low. The June counts of the 40 plots planted with untreated seed cane of CP 70-321 gave 16 shoots with mosaic among 3781 shoots, and those planted with hot-water treated seed cane gave one shoot among 2168 shoots.

#### DISCUSSION

The results of this series of experiments show that the serial hot-water treatment can control sugarcane mosaic in seed cane of CP 65-357, CP 72-356, and CP 72-370. The level of control in the fall of 1986 (Table 3, Experiments 1-6) may be taken as the level of control for the new shoots, and the difference between the control in the fall and that of the following June may be considered the result of spread of virus within the seed cane, assuming that the mosaic incidence in CP 70-321 indicates natural infection levels. Although the level of control can be increased, as for example, by removing the youngest nodes of the shoot in CP 65-357 or by leaving these nodes intact in CP 72-356, the basic problem remains that of eliminating all virus; any virus left in the seed cane or bud in a position to infect one shoot can, after multiplication, infect most of the other shoots as well.

In Louisiana, the combination of whole-stalk planting and the dependence of young shoots on the seed cane during the winter months maximizes the chance of this internal spread and re-establishment of infection and limits the potential of heat treatment to control this virus disease, even though the sugarcane mosaic strains dominant in Louisiana (Strains H and I) are relatively easily heat inactivated (6).

From a virological standpoint, it is notable, given the heterogeneity of the tissues of the stalk, that so many of the shoots that grow from hot-water treated seed cane are free of symptoms. It shows that viral nucleic acid or nucleoprotein is inactivated while the cellular machinery, including the plant's nucleic acids and proteins, remains functional, and the cells remain capable of dividing and organizing into tissues and organs.

The hot-water treatment had been selected to give a level of survival for CP 65-357 approaching that of untreated shoots. The variety CP 70-321 had been included in this experiment to have a mosaic-free control as well as to have a variety which in the long hot-water treatment (50°C for 2 hrs) has appeared to be susceptible to heat injury. The level of survival in various varieties has increased when the duration of the second or third treatment of the treatment series is shortened by five minutes (Benda, unpublished), and such changes might benefit the survival of CP 70-321 and CP 72-370; however, such changes may affect the level of control. The varieties CP 65-357 and CP 72-356 and, less so, CP 72-370 responded to the hot-water treatment series with a germination comparable to that of untreated cane if only Experiments 2 to 6 are considered (Table 2).

The control data in April and June (Table 3) are believed to be indicative of the level of control to be expected at harvest. In two experiments (one in 1978 and the other in 1981) with various varieties and various hot-water treatment schedules including untreated controls, it was noted that the proportion of shoots with mosaic symptoms among all shoots--from counts made in April, May, or June--is highly correlated ( $r > 0.95$ ) with the proportion of stalks with mosaic symptoms among all stalks at harvest the following November or December. These two experiments had been planted at the same rate (one running stalk or less) as the present eight experiments.

As a field method, this serial hot-water treatment would have the added advantage that it would cure the ratoon stunting disease (Benda, unpublished); the principle that more intensive heat treatments cure all the diseases that less intensive heat treatments cure is well established (6).

In order to apply this method as a field method in Louisiana certain precautions need to be observed to ensure the survival of the cane. The seed cane needs to be cut from stubble three to five days before the beginning of the treatment, and the green sheaths should be left to cover the buds. After treatment, the cane should be planted promptly and covered lightly, and soil should be added when the cane marks the row.

Planting of seed cane treated for sugarcane mosaic should be restricted to a period between Experiment 2 (September 4) and Experiment 6 (October 1). It may be necessary to keep the minimum air temperature to which the cane is exposed between cutting and planting between 20 and 30°C. In addition, the site where the cane is planted should be selected to be in an area of low mosaic spread.

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CONTROL OF MORNINGGLORY (IPOMOEA COCCINEA) IN  
SUGARCANE WITH LAY-BY HERBICIDE TREATMENTS

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ABSTRACT

Preemergence herbicide treatments were applied following the last cultivation (lay-by) of sugarcane on soils ranging from a silty clay loam to a silty clay that were heavily infested with red morningglory (Ipomoea coccinea L.). Morningglory control in an initial experiment, evaluated 60 days after herbicide treatment, was 84 and 92% for atrazine at 1.68 and 2.8 kg/ha; 79 and 91% for hexazinone at 0.56 and 0.79 kg/ha; 56 and 76% for diuron at 1.68 and 2.24 kg/ha; and 55% for cyanazine at 2.24 kg/ha. Some stunting was noted with hexazinone, but the other herbicide treatments did not injure sugarcane excessively. In a more extensive evaluation of atrazine, rates of 1.68, 2.24 and 2.8 kg/ha gave on average 91, 96, and 98% control of morningglory, respectively, when evaluated 90 days after treatment. Atrazine at rates of 2.24 and 2.8 kg/ha produced yields that were equal to the weed-free control, indicating that these treatments would be an adequate alternative to the standard aerial 2,4-D treatment. In the nontreated control, yield of sugar/ha was reduced 24 to 30% as compared to a weed-free control.

INTRODUCTION

The important species of annual morningglory or "tie vines" found in Louisiana sugarcane fields include: red (Ipomoea coccinea L.), ivyleaf or entireleaf (varieties of I. hederacea L.), smallflower (Jacquemontia tamnifolia L. Griseb.), and cypressvine (I. quamoclit L.).

Morningglories are a particular problem after the last cultivation (lay-by) of sugarcane in early June because they wrap around the cane stalks, cause deformed stalk growth, shade cane leaves, and interfere with machine harvesting. In Louisiana sugarcane, morningglory has been controlled with aerial applications of 2,4-D [(2,4-dichlorophenoxy)acetic acid]; however, the possibility of injuring sensitive crops or ornamentals by drift from 2,4-D has made alternative methods of control desirable.

Previous studies on the control of late-season sugarcane weeds with preemergence lay-by treatments have primarily concentrated on grass species, particularly johnsongrass [Sorghum halepense (L.) Pers.] and itchgrass [Rottboellia cochinchinensis (Lour.) Clayton] (2, 5). The herbicide trifluralin [2,6-dinitro-N,N-dipropyl-4-(trifluoromethyl)benzenamine] was found to control grasses but was not highly effective for control of morningglory, whereas terbacil [5-chloro-3-(1,1-dimethylethyl)-6-methyl-2,4(1H,3H)-pyrimidinedione] at 1.3 kg/ha gave relatively good control of both grasses and morningglory (5).

This study was initiated to evaluate several other herbicides that are known to have potential for economical preemergence control of morningglory.

MATERIALS AND METHODS

Field experiments were conducted in 1981, 1982, and 1985 at the U. S. Sugarcane Research Farm near Chacahoula, Louisiana. The field used for the experiments had a heavy, relatively uniform infestation of red morningglory as the result of seeding two years prior to the experiments and then allowing the plants to produce seed. Sugarcane cultivar CP 65-357 was planted in autumn of 1979 and experiments were conducted in 1981 and 1982 on the first- and second-ratoon crops, respectively, at separate locations within the field. After a fallow period of six months, which allowed morningglory to reseed, sugarcane cultivar CP 65-357 was replanted in autumn of 1983, and the 1985 experiment was conducted on the first-ratoon crop.



The soil in the field ranged from a Mhoon silty clay loam to a Mhoon silty clay with the following characteristics:

Texture	pH	Organic matter (%)	Cation exchange capacity (meq/100 g)	Sand (%)	Silt (%)	Clay (%)
Silty clay loam	6.4	1.5	15.9	12	53	35
Silty clay	6.3	1.7	16.7	11	47	42

Early season weeds were controlled with application of pendimethalin [N-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzenamine] at 2.2 kg/ha in March and an application of 2,4-D at 1.1 kg/ha in May. Both were applied to a 76-cm band over the lines of sugarcane which were spaced 1.8 m apart.

The herbicides evaluated in 1981 were: atrazine [6-chloro-N-ethyl-N'-(methyl-ethyl)-1,3,5-triazine-2,4-diamine]; cyanazine [2-[[4-chloro-6-(ethylamino)-1,3,5-triazin-2-yl]amino]-2-methyl-propanenitrile]; diuron [N'-(3,4-dichlorophenyl)-N,N-dimethylurea]; and hexazinone [3-cyclohexyl-6-(dimethylamino)-1-methyl-1,3,5-triazine-2,4(1H,3H)-dione]. Based on the results that year, a more extensive evaluation of atrazine was conducted in 1982 and 1985. In all experiments, herbicides were applied following the last cultivation in early June. The herbicide-water mixtures were applied broadcast to the interrow (1.7 m) with a tractor-mounted boom sprayer at 374 l/ha; the spray was directed to minimize wetting the sugarcane plants. All herbicide treatments were applied essentially preemergence to weeds.

Treatments were arranged in randomized complete block designs with four replications in both 1981 and 1982 and six replications in 1985. Plot size was three rows (5.3 m) x 12.2 m. In 1982 two experiments were conducted in the same field, one on the silty clay loam portion of the field and the other on the silty clay portion.

Surviving morningglory plants were counted at 60 days after treatment in 1981 and 90 days after treatment in 1982 and 1985. In 1981, the experiment was accidentally terminated when over-sprayed with 2,4-D about 70 days after treatment. In 1982, the amount of cane wrapped with vines was obtained 120 days after treatment by measuring the length of sugarcane row in each plot that contained at least one vine. All vines were removed by hand about one month before harvesting in November.

Sugarcane yields were obtained in early November of 1982 and 1985 experiments. The cane was cut by machine, weighed, and a 15-stalk sample from each plot was collected. The sample was crushed once in a 3-roller sample mill, and the juice was analyzed for Brix by hydrometer and for sucrose by polarimetry using standard methods (4); and sugar content (sugar/ton of cane) was calculated by methods previously described (3). Yields were compared with a nontreated control and with a weed-free control, maintained by periodic hand weeding.

## RESULTS AND DISCUSSION

The effects of herbicide treatments in 1981 on the number of surviving red morningglory plants and percent control are shown in Table 1. The most effective treatments were atrazine at 1.68 to 2.8 kg/ha, giving 82 to 92% control, and hexazinone at 0.56 and 0.79 kg/ha, giving 79 and 91% control, respectively. Diuron at 2.24 kg/ha provided 76% control and cyanazine at 2.24 kg/ha only 55% control.

Both rates of hexazinone caused some stunting of sugarcane (Table 1). Sugarcane was tolerant to the atrazine and cyanazine treatments and was generally tolerant to diuron. Injury to sugarcane by hexazinone has been observed in other studies (6), and such phytotoxicity has limited use of this herbicide.

A more extensive evaluation of morningglory control with atrazine was conducted in 1982 on silty clay loam and silty clay soils, and the results are shown in Table 2. A heavy infestation of morningglory, averaging 13 plants/m<sup>2</sup>, was present in the field. On both soil types, the number of surviving morningglory plants generally decreased as the rate of atrazine increased from 1.68 to 2.80 kg/ha. Likewise the amount of sugarcane wrapped by vines decreased as the rate increased (Table 2).

Table 1. Comparison of herbicide treatments at lay-by for preemergence control of red morningglory (MG) in CP 65-357 sugarcane, 1981.

Herbicide and rate (kg/ha)	Surviving (MG) plants and % control		Sugarcane injury rating (0-10) <sup>2/</sup>
	60 days after treatment <sup>1/</sup> (no/m <sup>2</sup> )	(%)	
Atrazine - 1.68	0.75 ab	84	0.0
Atrazine - 2.24	0.85 ab	82	0.0
Atrazine - 2.80	0.35 a	92	0.0
Cyanazine - 2.24	2.10 c	55	0.0
Diuron - 1.68	2.18 c	53	0.0
Diuron - 2.24	1.14 b	76	0.2
Hexazinone - 0.56	1.00 ab	79	1.0
Hexazinone - 0.79	0.40 a	91	1.0
Nontreated control	4.70 d	0	0.0

<sup>1/</sup> Mean counts followed by the same letter are not significantly different at the 5% level of probability as determined by the Duncan's Multiple Range Test.

<sup>2/</sup> 0 = no injury; 10 = all plants killed.

Table 2. Effect of atrazine treatments and soil texture on control of red morningglory (MG) in 1982.

Herbicide and rate (kg/ha)	Surviving (MG) plants and % control				Sugarcane wrapped with vines 1 mo before harvest <sup>2/</sup>	
	by soil texture at 90 days after treatment <sup>1/2/</sup>					
	Silty clay loam		Silty clay		Silty clay loam	Silty clay
	(no/m <sup>2</sup> )	(%)	(no/m <sup>2</sup> )	(%)	(% of row length)	
Atrazine - 1.68	0.91 b	93	1.53 c	88	56 c	79 c
Atrazine - 2.24	0.34 a	98	0.67 b	95	25 b	45 b
Atrazine - 2.80	0.26 a	98	0.35 a	97	15 a	21 a
Nontreated control	12.83 c	0	13.11 d	0	97 d	97 d

<sup>1/</sup> A statistical analyses of the number of surviving plants showed a significant interaction between soil type and atrazine treatment.

<sup>2/</sup> Means in each column followed by the same letter are not significantly different at the 5% level of probability as determined by the Duncan's Multiple Range Test.

A statistical analysis of the number of morningglory plants that survived on the two soil types showed a significant interaction, indicating that the performance of atrazine was being affected by soil type (Table 2). Atrazine generally controlled morningglory more effectively on silty clay loam than on silty clay. The control on the two soils was influenced by the rate of atrazine, with the lowest rate most affected. Atrazine is adsorbed by the clay and organic matter fraction of soil (1, 7), and increases in these fractions would probably increase the rate of atrazine needed for control.

No interaction was found between yield and soil type in 1982, and consequently, yield data for the two experiments were combined (Table 3). Cane yield and sugar/ha yields were significantly higher for atrazine treatments than for the nontreated control. Atrazine at 1.68 kg/ha produced yields of cane/ha and sugar/ha that were about 6% lower than the weed-free control, whereas the higher rates of atrazine produced yields that were not significantly different from the weed-free control. The nontreated control produced yields of cane/ha and sugar/ha that were about 24% lower than those of the weed-free control or atrazine-treated cane.

Table 3. Yield of CP 65-357 sugarcane as affected by lay-by atrazine treatments for control of red morningglory in 1982 (averages from combining experiments on silty clay loam and silty clay).

Herbicide and rate (kg/ha)	Yield <sup>1/</sup>		
	Cane/ha (ton)	Sugar/ton of cane (kg)	Sugar/ha (kg)
Atrazine - 1.68	77 b	107 a	8200 b
Atrazine - 2.24	84 a	107 a	8900 a
Atrazine - 2.80	80 ab	108 a	8700 ab
Weed-free control	82 a	107 a	8800 a
Nontreated control	63 c	107 a	6700 c

<sup>1/</sup> Treatment means in each yield category followed by the same letter are not significantly different at the 5% level of probability as determined by the Duncan's Multiple Range Test.

In the 1985 experiment, the number of surviving morningglory plants decreased significantly as the rate of atrazine increased from 1.68 to 2.8 kg/ha, with control ranging from 91 to 98% (Table 4). Mixing pendimethalin at 2.2 kg/ha with atrazine at 1.68 kg/ha improved control over atrazine at 1.68 kg/ha, but mixing pendimethalin with atrazine at 2.2 kg/ha did not improve control. Atrazine alone will not control johnsongrass and itchgrass, whereas pendimethalin will control these weeds (Millhollon, unpublished data). Thus, a mixture of the two herbicides could be an effective lay-by treatment to enhance control of both grasses and morningglory.

Table 4. Effect of lay-by treatments on control of red morningglory and on yield of CP 65-357 sugarcane in 1985.

Herbicide and rate (kg/ha)	Surviving plants and % control at 90 days after treatment <sup>1/</sup>		Yield <sup>1/</sup>			
	(no/m <sup>2</sup> )	(%)	Millable stalks/ha (no)	Cane/ha (ton)	Sugar/ton of cane (kg)	Sugar/ha (kg)
Atrazine - 1.68	1.05 d	91	59,900 ab	60 a	132 a	7900 a
Atrazine - 2.24	0.43 b	96	63,400 a	64 a	133 a	8400 a
Atrazine - 2.80	0.25 a	98	59,800 ab	60 a	139 a	8400 a
(Atrazine - 1.68 + Pendimethalin - 2.2)	0.71 c	94	61,200 ab	61 a	133 a	8100 a
(Atrazine - 2.24 + Pendimethalin - 2.2)	0.57 b	95	58,200 b	59 a	135 a	8000 a
Weed-free control	-	100	59,600 ab	61 a	137 a	8300 a
Nontreated control	12.00 e	0	48,100 c	44 b	131 a	5800 b

<sup>1/</sup> Means followed by the same letter in a column are not significantly different at the 5% level of probability as determined by the Duncan's Multiple Range Test.

All of the treatments in the 1985 experiment produced cane yields and sugar/ha that were equivalent to the weed-free control (Table 4). The nontreated control produced yields of cane and sugar/ha that were 28 and 30% below the weed-free control or herbicide-treated plots. A reduction in the number of millable stalks/ha was primarily responsible for this yield reduction.

The population of red morningglory in these experiments was much higher than normally would be encountered in commercial sugarcane fields. Since atrazine effectively controlled morningglory under these conditions, it should be considered as an alternative to 2,4-D for control of this weed in sugarcane.

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EFFECTS OF GROWTH REGULATORS ON TILLERING, FLOWER CONTROL  
AND RIPENING OF SUGARCANE IN THE LOWER RIO GRANDE VALLEY OF TEXAS<sup>1/</sup>, <sup>2/</sup>

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ABSTRACT

In four separate field studies, the potential effect of growth regulators to stimulate tillering, to suppress tasseling, and to enhance ripening of sugarcane cultivar NCo 310 were evaluated in the Lower Rio Grande Valley of Texas. In the first test, broadcast applications made at the time of planting had no effect on sugarcane tillering while later applications had herbicidal effects on existing foliage. The second test showed that among various seedpiece treatments evaluated, dipping seedpieces in a bath containing the growth regulator ethephon increased tillering in the subsequent plant cane sugarcane crop. The third test showed that ethephon application between September 9th and 22nd completely eliminated tasseling in a field in which over 80% of the stalks of the untreated control tasseled, and eliminated stalk pithiness which normally develops with tasseling. However, the application of ethephon also resulted in extensive side shoots at the nodes and a loss in total growth. The fourth test demonstrated ripening enhancement by the application of growth regulators; however, the response was not large. These experiments demonstrated the need for additional testing to more clearly define timing and rates of application for maximum response.

INTRODUCTION

Sugarcane is vegetatively propagated, therefore, planting is both labor intensive and expensive. When seedpieces are placed in the furrow, considerable overlap is necessary to insure adequate tillering density. Studies have indicated that certain plant growth regulator compounds can be used to increase tillering in newly planted sugarcane (2,6,10). Further as sugarcane matures, a physiological change from the vegetative to the reproductive mode generally occurs. Tasseling in sugarcane is triggered by daylength, but develops depending on climatic factors such as moisture and temperature. When tasseling occurs, cane quality usually deteriorates within two to four months. To prevent tasseling at harvest would improve quality and therefore increase yields.

A primary effect of most growth regulators on sugarcane appears to be to interrupt terminal growth (9), but various effects on carbon partitioning patterns involving source and sink activity have been suggested (1). Several studies have indicated that growth regulators enhance the maturation process (4,5,7,8,9), although detrimental side effects including the loss of additional growth (1,8) and stimulation of axillary shoots (8) have also been reported. The greatest ripening effect appears at five to seven weeks following treatment (1,4,5,8,9), after which the sugar per unit area in the untreated cane usually approaches that in the treated cane.

The purpose of this study was to evaluate several growth regulator compounds on sugarcane in South Texas to determine their effectiveness for tiller stimulation, tassel control and ripening enhancement.

MATERIALS AND METHODS

Four separate field tests were conducted to evaluate growth regulator compounds as described in the objectives stated above.

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<sup>2/</sup> Mention of a trademark or a proprietary product does not constitute a guarantee or a warranty by the Texas Agricultural Experiment Station and does not imply its approval to the exclusion of other products that also may be suitable.

#### Test 1 - Broadcast application to enhance tillering

Sugarcane (cultivar NCo 310) was planted on December 2, 1985, on a Hidalgo sandy clay loam soil (Typic Calciustolls) at the Texas A&M Center at Weslaco. The crop was vegetatively propagated by placing overlapping stripped-stalk seedpieces in furrows spaced 152 cm (60 in.) apart and then covering with approximately 15 cm of soil. Fertilization consisted of a single application of N at 168 kg N/ha in March. Weeds were controlled with mechanical cultivation, hand hoeing, and spot application with glyphosate herbicide (Roundup, Monsanto). Five applications of monocrotophos (Azodrine 5, Shell Chemical) were made for Mexican rice borer (Eoreuma loftini) control.

Treatments consisted of an experimental American Cyanamid compound, AC 117438, at four rates: 75, 125, 175, and 225 gms ae/ha, and the compound ethephon (2-chloroethyl) phosphoric acid, Union Carbide) at 1120 gm ae/ha (label recommended rate). Further, applications were made at three developmental stages of the crop: pre-emergence (12/2/85), spike stage (2/7/86), and when the plants were 30 to 50 cm tall (3/21/86). All treatments were replicated four times in a randomized block design in plots 4 rows wide by 9.1 m (30 ft) in length.

Data obtained consisted of tiller counts in each plot on five dates (shown in Table 1) from one month to one year following application and cane yield on 2/12/87. A 15-stalk sample was first taken from one of the two middle rows, weighed, stripped of leaves and tops, then reweighed to obtain a trash percentage for the cane in each plot. The stalk samples were then milled and the juice was analyzed for refractometer solids, sucrose content via polarimetry, and electrical conductivity. After the 15-stalk samples had been removed from each plot, the remaining plot area was burned and one whole row from each plot was harvested and weighed. The data obtained were used to calculate cane yield, juice purity, cane sugar content [using the Winter-Carp formula (3)], and yield of sugar per unit area.

#### Test 2: Seedpiece treatments to enhance tillering

This test was conducted by applying treatments to sugarcane (cultivar NCo 310) seedpieces prior to planting. Treatments consisted of: ethephon application (2.24 kg ae/ha) to standing cane three weeks prior to harvest intended for seedcane use; cold water dip for approximately 20 minutes in solutions containing ethephon at 0, 250 or 500 ppm; and an untreated check. Dip treatment and planting were done on November 7, 1986. Treatments were arranged in a randomized block design with four replications. The seedpieces were cut into 1.2 m (4 ft) lengths and were planted end-to-end without overlap in plots 4 rows wide by 9.1 m in length. Before covering the seedpieces, the total number of eyes planted in each plot were counted. Standard cultural practices for the area as described previously were applied to obtain maximum production.

Data collected included total number of tillers in each plot on seven dates from 81 to 266 days following planting. Relative tillering was calculated as the actual number of tillers as a percentage of the total number of eyes planted.

#### Test 3: Tassel control

An established field of sugarcane (cultivar NCo 310) located in eastern Hidalgo County near Santa Rosa, Texas, was selected for use in this test. Two rows along one edge of the field were removed by harvesting in late August 1986 in order to permit access for treatment applications to inner rows that were unaffected by border effects. Ethephon treatments at the rate of 840 gms ae/ha were made on each of four dates: September 9, 15, 18 and 22, 1986. Treatments were replicated four times in a randomized block design in plots 9.1 m in length separated by 3.1 m alleys, and were applied using a custom-built sprayer consisting of a CO<sub>2</sub> pressurized system and a side spray boom which covered five rows.

The treated areas, as well as the alleyways, between plots were checked regularly to determine whether tassel initiation had occurred. Selected stalks were split to determine whether the primary growing point had transformed from a vegetative to a flowering primordia.

The effect of ethephon treatment on sugarcane was determined by taking 15-stalk samples from treated and untreated (where tasseling occurred) areas on two dates - January 13 and 20, 1987. The measurements made on each stalk included total length, green and dry weights, number of internodes, number of secondary shoots off the main stalk, number and length of pithy internodes, and weight of pithy and solid internodes.

#### Test 4: Chemical ripening

A field of sugarcane (cultivar NCo 310) was grown for use in this test on the same soil type and using the same planting procedures and cultural practices as described previously in Test 1. Treatments consisted of application on September 3, 1986, of the American Cyanamid compound AC 117438 at 80, 160 and 240 gms ae/ha; glyphosate [Polado, sodium sesqui salt of (N-(phosphonomethyl) glycine)] (Monsanto) at 500 gms ae/ha; and an untreated check. Treatments were applied to plots 9.1 m in length by 4 rows wide and were replicated six times in a randomized block design.

Juice refractometer solids (RFS) was determined on seven dates up to fourteen weeks following application by selecting a single stalk from each plot, cutting a 2-3 cm section, then squeezing with a modified pair of pliers to obtain enough juice for a reading with a hand refractometer. Net cane yield, trash percentage, juice quality parameters and sugar yield were determined on February 9, 1987, as described for Test 1.

### RESULTS AND DISCUSSION

#### Test 1: Broadcast application to enhance tillering

Tiller counts indicated that soil application of the growth regulators at or following planting either had no effect or had an effect which proved undesirable. All pre-emerge applications (12/2/85) had no significant effect on tiller counts on any date relative to the untreated check regardless of material or rate of application (Table 1).

Table 1. Tiller counts on five dates for the various timing, compound, and rate treatments applied in Test 1: Broadcast application to enhance tillering.

Application			Date				
Timing	Compound	Rate	2/07/86	3/20/86	5/01/86	7/10/86	3/05/87
		gm a/ha	#/m <sup>2</sup>				
	None	0	.12	.32	1.06	1.60	3.21
Pre-emerge (12/2/85)	Ethephon	1120	.13	.35	1.15	1.75	2.56
	AC 117438	75	.12	.33	1.06	1.62	2.81
		125	.09	.30	1.01	1.65	2.39
		175	.11	.33	.98	1.62	2.56
		225	.12	.33	1.05	1.61	2.65
	Significance <sup>1/</sup>		ns	ns	ns	ns	ns
Spike stage (2/7/86)	Ethephon	1120	--	.31	1.12	1.73	2.91
	AC 117438	75	--	.33	.86	1.55	2.68
		125	--	.32	.98	1.68	3.07
		175	--	.28	.76	1.51	2.36
		225	--	.29	.78	1.58	2.83
	Significance			ns	ns	ns	ns
30 to 50 cm stage (3/21/86)	Ethephon	1120	--	--	.89	1.92	3.28
	AC 117438	75	--	--	.89	1.61	2.62
		125	--	--	.45	1.39	2.96
		175	--	--	.43	1.30	2.40
		225	--	--	.40	1.14	2.43
	Significance				**	*	ns

#### Statistical significance of various mean differences

Treated vs Untreated	ns	ns	***	*	ns
Compound	ns	ns	***	***	ns
Timing		ns	***	*	ns
Pre-emerge			a	a	
Spike-stage			b	a	
30 to 50 cm			c	b	

<sup>1/</sup> Differences between means are not significant (ns) or significant at the 5% (\*), 1% (\*\*) or 0.1% (\*\*\*) levels. Where different treatments are marked with the same letter, means were not statistically different at the 5% confidence level.



Applications made at the spike stage (2/7/86) caused no effect on tiller counts on March 20; however, AC 117438 as on average of all rates resulted in significantly lower counts on May 1 when compared to pre-emerge treatments or the untreated check. However, when considering each individual rate, there was no effect on tiller counts on May 1. Application of growth regulators at the spike-stage had no effect on tiller counts compared to pre-emerge application on the untreated check on July 10, 1986, and March 5, 1987, indicating recovery from the injury that was evident on May 1. Growth regulator applications made when the cane was 30 to 50 cm tall (3/21/86) caused significant reductions in tiller counts on May 1 compared to the pre-emerge and spike stage applications. Furthermore, increasing rate of the compound AC 117438 applied at the 30 to 50 cm of height caused a significant decrease in the tiller counts on May 1. The detrimental effect of AC 117438 applied at this time continued until July 10. Increasing rate of application of AC 117438 at 30 to 50 cm of height also continued to have a significant effect on tiller counts on July 10. However, there were no significant differences in tiller counts in the subsequent stubble crop due to any of the treatments. The large degree of variability between replicates indicated that the number of cane tillers had recovered from any injury detected the previous year.

The effect on yield of cane from this test further indicated that the later the application of growth regulator, the greater the reduction in growth. As an average of all rates, AC 117438 appeared to increase net cane yields when compared to the control when applied as a pre-emerge treatment (Table 2).

This effect was significant at the 6.6 confidence level, but is the only indication of a beneficial effect found in this test. Growth regulator application at the spike stage had no statistically significant effects on any of the yield or quality parameters relative to the untreated check. When AC 117438 was applied to 30 to 50 cm height there was a decrease in net cane yield, an increase in trash, lower juice quality parameters except for electrical conductivity, a decrease in cane sugar content, and lower sugar yields when compared to both the untreated check and pre-emerge application. Furthermore, increasing rate of AC 117438 at 30 to 50 cm of height resulted in linear decreases in net cane yield, juice purity and sugar yield.

#### Test 2. Seedpiece treatments to enhance tillering

Seedpiece treatment with ethephon caused an increase in tillering in the plant cane crop (Figure 1). Dipping the seedpieces in a solution containing 500 ppm ethephon resulted in significantly greater tiller numbers relative to the number of eyes planted than any other treatment including the untreated check at 178, 195 and 223 days after planting. The 500 ppm dip also resulted in more tillers than all other treatments except the 250 ppm ethephon dip at 266 days following planting. Improvements in tillering by the 500 ppm ethephon dip over the untreated check were as high as 23% at 195 days after planting (May 21st) but decreased thereafter as all treatments experienced a decline in tiller numbers.

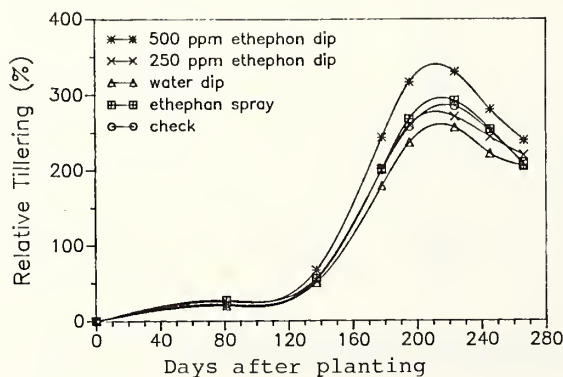


Figure 1. Effects of several preplant seedpiece treatments on subsequent sugarcane tiller development in Test 2: Seedpiece treatments to enhance tillering. Relative tillering was determined as the number of tillers as a percentage of the total number of nodes planted.



Table 2. Sugarcane yield and juice quality parameters measured at harvest for the various timing, compound, and rate treatments applied in Test 1: Broadcast application to enhance tillering.

Application Timing	Compound	Rate	Net Cane Yield	Trash	RFS <sup>1/</sup>	Pol <sup>2/</sup>	Purity <sup>3/</sup>	Electrical Conductivity	Cane Sugar Content	Sugar Yield
		gm a/ha	kg/ha	%	%	%	%	mmhos	%	kg/ha
-	None	0	99,100	23	19.2	17.5	91.0	5.1	13.1	13,070
Pre-emerge (12/2/85)	Ethephon	1120	99,700	27	18.7	17.0	90.8	4.9	12.7	12,670
	AC 117438	75	100,900	23	19.3	17.5	90.6	5.6	13.1	13,230
		125	107,200	25	19.1	17.3	90.7	5.7	13.0	13,940
		175	109,900	24	19.0	17.2	90.7	5.3	12.9	14,160
		225	112,000	23	18.5	16.7	90.3	6.0	12.5	13,970
		Significance <sup>4/</sup>	ns	ns	ns	ns	ns	ns	ns	ns
Spike-stage (2/7/86)	Ethephon	1120	108,400	24	18.6	16.8	90.4	5.4	12.6	13,570
	AC 117438	75	100,000	26	18.8	17.1	90.6	4.8	12.8	12,770
		125	104,300	24	18.4	16.5	89.8	5.8	12.3	12,780
		175	94,800	24	19.0	17.1	89.9	5.3	12.8	12,110
		225	89,100	26	19.1	17.3	90.5	5.3	13.0	11,560
		Significance	ns	ns	ns	ns	ns	ns	ns	ns
30-50 cm stage (3/21/87)	Ethephon	1120	92,100	25	19.0	17.2	90.6	5.3	12.9	11,870
	AC 117438	75	95,400	27	19.0	17.3	91.1	5.4	13.0	12,360
		125	7,600	25	18.2	16.4	90.0	5.7	12.2	8,650
		175	46,000	31	17.8	15.8	88.3	5.4	11.7	5,350
		225	32,900	32	18.1	16.1	88.7	5.4	11.9	3,950
		Significance	***	ns	ns	ns	**	ns	ns	***
Statistical significance of various mean differences										
Treated vs Untreated			***	***	**	**	**	ns	**	***
Compound			ns	ns	ns	ns	ns	ns	ns	ns
Timing			***	**	*	*	ns	ns	*	***
Pre-emerge			a	a		a	a		a	a
Spike-stage			a	a		ab	ab		ab	a
30-50 cm			b	b		b	b		b	b

<sup>1/</sup> Refractometer dissolved solids in juice.

<sup>2/</sup> Polarimeter sucrose content in juice.

<sup>3/</sup> Percent of RFS as sucrose [(Pol/RFS) x 100].

<sup>4/</sup> Differences between means are not significant (ns) or significant at the 5% (\*), 1% (\*\*) or 0.1% (\*\*\*) levels. Where different treatments are marked with the same letter, means were not statistically different at the 5% confidence level.

### Test 3: Tassel control

No evidence of tassel initiation was ever found in or near the treated areas. However, in late November, tasseling began to occur throughout the rest of the field and continued through January until approximately 80% of the stalks had tasseled. Application of ethephon at the rate of 840 gms/ha between September 9th and 22nd caused complete tassel control. It was apparent that rates below 840 gms/ha would likewise be effective since drift onto adjacent areas also resulted in complete tassel control.

The application of ethephon caused several distinct changes in the growth and development of sugarcane besides preventing tasseling (Tables 3 and 4). Growth was reduced substantially by ethephon as stalks were 16% shorter and contained fewer internodes than untreated stalks. Ethephon treated stalks had no pith, while untreated stalks contained appreciable pith. However, the number of nodes with secondary side shoots and bulging buds was increased substantially by ethephon over the untreated check. Apparently, ethephon released the apical dominance thus increasing sprouting of axillary shoots.

Table 3. Effects of ethephon application in mid-September (complete tassel control) vs untreated (80% tasseling) on various sugarcane growth and stalk quality parameters on two dates in Test 3: Tassel control.

Sample date	Treatment	Stalk length	Stalk wt		Number internodes	Number lalas	Number bulging eyes	Pithy Internodes		Weight	
			Green	Net				Number	Length	Pithy	Solid
		m	--kg--						m	--kg--	
Jan 13	Untreated	2.67	1.58	1.35	25.4	1.1	.47	8.9	.67	.19	1.22
	Ethephon	2.26	1.23	1.07	22.3	5.2	3.67	0	0	0	1.07
Jan 20	Untreated	2.82	1.73	1.51	25.4	.6	.93	8.7	.64	.22	1.11
	Ethephon	2.36	1.53	1.33	23.4	3.0	4.29	0	0	0	1.33

Table 4. Comparison between ethephon application which caused complete tassel control vs untreated sugarcane for several stalk parameters in Test 3: Tassel control.

	Jan 13		Jan 20	
	Untreated	Ethephon	Untreated	Ethephon
% of nodes having secondary shoots	4.5	23.4	2.5	12.8
% of nodes having bulging eyes	1.8	16.5	3.6	18.3
TOTAL	6.3	39.9	6.1	31.1
Density of net cane (kg/m)	.505	.472	.549	.598
Density of pithy only (kg/m)	.281	-	.341	-
Density of non-pithy only (kg/m)	.579	-	.524	-
Green matter as a % of gross start cane	14.8	13.0	13.1	12.5

#### Test 4: Chemical ripening

The application of growth regulators in the fall of September 3, 1986, had only marginal effects on juice refractometer solids (RFS content) from seven weeks to four months after application (Table 5). Increasing rate of AC 117438 caused statistically significant increases in RFS content on the first, third, and seventh sample dates. On the other dates, any change in RFS content with rate of AC 117438 applied was not enough to be significant. Furthermore, when comparing the effect of the two compounds (Polado or AC 117438 averaged across rate) vs the untreated check, neither had a statistically significant effect on juice RFS content on any sample date.

Sugarcane yield and juice quality data for this ripening test showed additional differences due to fall application of growth regulators (Table 6). Application of growth regulators had no significant effect on net cane yield; however, application of the two compounds increased the trash percentage relative to the untreated check. Application of growth regulators also caused a significant increase in juice RFS over the untreated check and an increase in juice RFS with increasing rate of AC 117438 applied. Juice polarimeter sucrose content, juice purity, and cane sugar content were also increased significantly by growth regulator application over the untreated check. These effects, however, were not adequate to result in any significant growth regulator effects on net sugar yields.

Table 5. Refractometer dissolved solid (RFS) content of juice on seven dates for the various compound and rate treatments applied on Sept. 3 in Test 4: Chemical ripening.

Compound	Rate	Date						
		10/27	11/17	11/24	12/04	12/10	12/17	01/12/87
	gms a/ha							
None	0	15.0	16.9	17.5	18.6	17.9	18.1	18.5
Polado	500	15.4	18.7	18.3	20.3	19.3	18.3	19.7
AC 117438	80	14.8	16.9	18.7	18.9	17.6	16.8	18.8
	160	15.7	19.0	17.8	19.4	16.4	17.7	19.6
	240	16.9	18.7	20.1	19.9	16.8	17.0	20.4
	Significance <sup>1/</sup>	*	ns	*	ns	ns	ns	*

Statistical significance of various mean differences

Treated vs untreated	ns	ns	ns	ns	ns	ns	ns	ns
Compound	ns	ns	ns	ns	*	ns	ns	ns

<sup>1/</sup> Differences between means are not significant (ns) or significant at the 5% (\*) or 1% (\*\*) level.

Table 6. Sugarcane yield and juice quality parameters measured at harvest for the various compound and rate treatments applied in Test 4: Chemical ripening.

Compound	Rate	Net cane yield	Trash	RFS <sup>1/</sup>	Pol <sup>2/</sup>	Purity <sup>3/</sup>	Electrical conductivity	Cane sugar content	Sugar yield
		kg/ha	%	%	%	%	mmho's	%	kg/ha
None	0	108,400	20	18.0	16.2	89.9	5.7	12.1	13,050
Polado	500	96,000	24	18.7	17.0	90.9	5.4	12.7	12,200
AC 117438	80	113,600	23	18.9	17.2	91.0	4.6	12.9	14,660
	160	105,900	22	19.0	17.2	90.3	5.6	12.9	12,640
	240	104,800	22	19.8	18.1	91.2	5.4	13.6	14,170
	Significance <sup>1/</sup>	ns	ns	**	**	ns	ns	**	ns

Statistical significance of various mean differences

Treated vs untreated	ns	**	*	*	*	ns	*	ns
Compound	ns	ns	ns	ns	ns	ns	ns	*

<sup>1/</sup> Refractometer dissolved solids in juice.

<sup>2/</sup> Polarimeter sucrose content in juice.

<sup>3/</sup> Percent of RFS as sucrose [(Pol/RFS) x 100].

<sup>4/</sup> Differences between means are not significant (ns) or significant at the 5% (\*) or 1% (\*\*) level.

### CONCLUSIONS

Broadcast growth regulator applications applied to enhance tillering showed that delivery of such compounds through the soil is ineffective. However, broadcast applications to foliage may have a herbicidal effect before the material can have a positive effect on tillering. The seedpiece treatments evaluated to enhance tillering showed that this is an effective method of delivery, overcoming the problems found with broadcast application. Further evaluation is necessary to determine optimum rate since this study indicated that seedpiece dipping at rates above 500 ppm ethephon may continue to increase the response. If seedpiece treatment with ethephon is effective then further study is also needed to determine optimal planting rate.

Ethephon application is a useful tool for tassel control in sugarcane in South Texas. In this study, control of tasseling would not have resulted in increased sugar yields since lost growth and axillary shoot sprouting occurred. Further study

is again necessary to determine optimum timing so that tasseling is controlled with the least amount of growth loss, and an optimum rate must be identified which will control tasseling with the least detrimental side effects.

Ripening of sugarcane cultivar NCo 310, later maturing variety, appeared to be enhanced by fall growth regulator applications. The effects were rather small, but the ripening benefits may have been larger prior to when sampling began. Again, further study is needed to determine optimum timing and rate of application to obtain the greatest benefit.

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## ROTALON - AN ENGINEERING MATERIAL FOR THE SUGAR INDUSTRY

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### INTRODUCTION

Over the last few years Smith Mirrlees of Glasgow, Scotland, has developed and tested a special recipe nylon material for engineering applications in the sugar industry. The material is called Rotalon and this paper sets out its technical properties and details of some of the trials that have been carried out. The development of Rotalon is an example of the trend within the engineering industry to replace traditional materials, particularly brass, steel and iron, with alternatives which give better performance and are easier to handle.

### TECHNICAL DATA

Nylon is the best known of the thermoplastics; it is also the toughest and hardest wearing. There are three main production methods used: injection molding, extrusion and monomer casting. Each of these methods produces nylon with different average molecular weights. For injection molded grades it is 15,000, for extrusion grades it is 48,000, and for monomer cast grades it is 90,000. The higher the molecular weight, the greater the toughness and the wear resistance of the nylon.

Rotalon is a special formulation of nylon which is monomer cast into engineering components for the sugar industry. For example, scraper tips are gravity cast into steel molds and mill roller bearings are spun cast. The Rotalon is poured into the molds as a monomer, and polymerization takes place as the casting sets.

Table 1. Rotalon properties - dry specimens.

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Melting point	220 degrees C.
Tensile strength at 23 degrees C.	13,000 p.s.i.
Elongation at yield	12%
Shore D hardness	80-85
Specific gravity	1.14
Saturation water absorption	8% Max

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In operation, Rotalon can withstand up to 120 degrees C. which should satisfy even the most arduous bearing applications as temperatures in excess of this are very unlikely, except if the lubrication or cooling systems fail. Figure 1 shows the range of dynamic bearings loads at differing surface speeds at 23 degrees C. For operation at 60 degrees C. these figures should be multiplied by a factor of 0.7.

The specific gravity of only 1.14 means that a component manufactured from Rotalon weighs just 15% of the same component in cast iron and 13% of it made in gunmetal. As an example a typical 84" scraper tip weighs about 40 kg in Rotalon and 260 kg in cast iron. Similarly, a bronze mill bearing weighing 170 kg weighs only 22 kg in Rotalon.

The water absorption of Rotalon is beneficial in terms of improved toughness and impact resistance. A sample measured at 3% absorption showed an impact reading improved three-fold, and this increased resilience contributes substantially to improved wear resistance. In practice Rotalon moisture absorption would not exceed 4%.

Table 2 shows the average values for the coefficient of friction of Rotalon. It has been dynamically measured at two surface loads, a high load of 2,000 p.s.i. and a low load of 100 p.s.i.

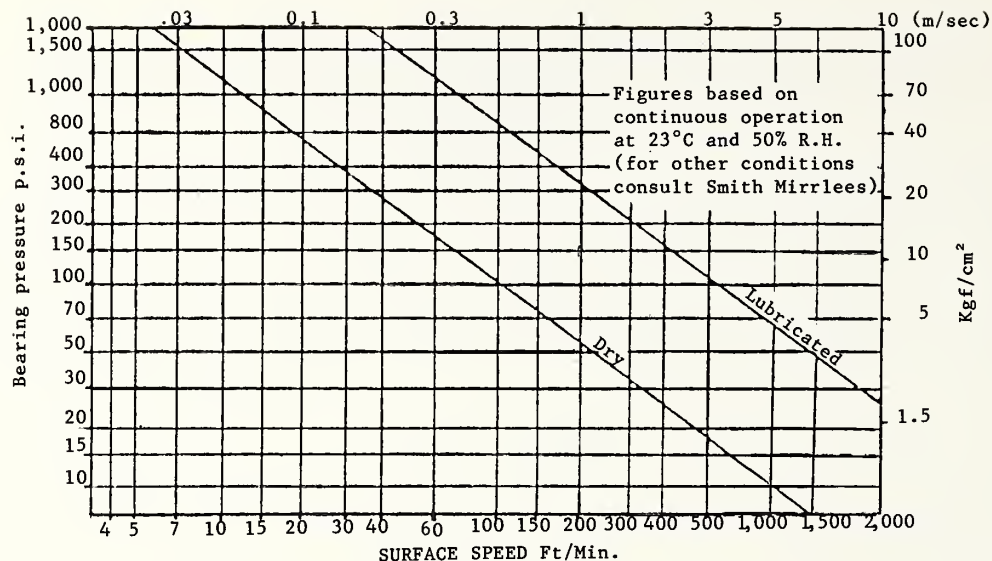


Figure 1. Allowable bearing loads - dynamic.

Table 2. Rotalon coefficients of friction.

Surfaces	Lubrication	Surface load/p.s.i.	Coefficients
Rotalon on Rotalon	None	2,000	0.80
Rotalon on Rotalon	Water	2,000	0.11
Rotalon on Rotalon	Oil	2,000	0.08
Rotalon on steel	None	2,000	0.40
Rotalon on steel	Water	2,000	0.07
Rotalon on Rotalon	None	100	0.15
Rotalon on steel	None	100	0.30
Rotalon on steel	Water	100	0.18
Bronze on steel	Oil	100	0.16

Theoretically, therefore, Rotalon is ideal for bearing, scraper and wear strip applications in the sugar industry. Related grades of Rotalon have been used in the mining, construction and automotive industries where duties are severe. After adjusting the recipe to suit sugar industry applications, it was with confidence that trials were set up in the sugar factories and refineries around the world.

#### Field trials

1. **Scraper Tips** - The first scraper tip was installed at Nakambala factory in Zambia in September 1985 on the 2nd mill. After a campaign of 200,000 tonnes of cane ground, wear on the Rotalon scraper tip was about 40% of the allowable maximum, representing 5% by weight, and most of it occurred during the initial "bedding-in" period. Other observations were that the bolt holes showed no wear or elongation, most of the wear was on the teeth tips and roots, and minimal tension was required on the tensioning spring. The wear on the roller was, therefore, significantly less.

For the second campaign of 1.2 million tonnes, which has just been completed, it was used on the 5th mill. There is no visible damage on the scraper tip, and it will be installed for a third campaign starting in November. Previous records at the factory show that their orthodox iron and steel mix scraper tips are replaced once or twice per campaign depending on their location.

As with all development work, particularly at the field trial stage, some setbacks were experienced and useful lessons learned. Mill roller scrapers were installed at Talisman, Atlantic and Belleglade factories in Florida for the 1986/87 crop.

Excessive wear was measured during the first days of the campaign which we now believe was due to a combination of the spring pressure and the amount of weld deposit that was used on the rollers. The same wear problems also affected the cast iron scrapers, in some cases to a greater extent. We now recommend that the scraper tip should only lightly touch the roller, and that the "bedding-in" period should be extended where heavy weld is used to allow the Rotalon to assume the new shape of the roller teeth. If both these actions are taken, we are confident that the problems experienced should be overcome.

On the positive side, an 84" Rotalon bagasse scraper tip operated throughout the recent record crop at Raceland Factory in Louisiana, where 588,000 tonnes of cane were crushed in 85 days. Tip wear, 3% by weight, was less than for the other cast iron scraper tips, and more importantly, roller wear was 40% less than on the other bagasse rolls. Extended life expectancy of the rollers is clearly the most important cost saving that is achieved using Rotalon scraper tips.

2. Bottom half top roller bearings - The first pair of Rotalon bottom half top roller bearings were installed in Simunye factory in Swaziland. The bearings were installed in March 1986 and after one campaign the performance was considered to be very satisfactory and certainly competitive with gunmetal. Twelve more bearings have been purchased for the new campaign to completely equip the tandem. Nakambala factory has also installed a pair of top roller bottom half bearings. After one campaign there are no signs of undue wear; the bearings were considered to be in good condition and are expected to give a longer operational life than the traditional bronze bearings.
3. Chain rollers - Rotalon was used to replace some of the steel rollers on carrier chain at Nakambala factory. The common problem of trash jamming the roller between the side bars remains and, as with steel, flats were worn on the rollers. However, dragging non-rotating Rotalon rollers over steel rails absorbs less power than conventional materials. A further trial will take place on Cobra outboard roller chain at the Monymusk factory in Jamaica during the 1987/88 crop.
4. Trash scrapers - Another example of a scraper application is at beet factories. Early in the process they separate the tops and tails from the beets using scrapers which continually run over a screen pushing them into a collecting vessel.

In the past, brass scrapers have been used, but due to cost, steel replaced them. This resulted in corrosion and wear on the stainless steel screen. Each unit has 16 scrapers, and for the first campaign one Rotalon scraper was tried which achieved comparable wear results. In the forthcoming campaign, reduction in screen wear is clearly where the major cost saving could be made.

5. Crystallizer bearings - Another application for Rotalon is the crystallizer bearings at Tate & Lyle's Greenock refinery in Scotland. Both end trunnions and the submerged mid bearings were fitted towards the end of 1986. It should be noted that a specially designed submersible bearing has been developed which prevents scouring of the rotating parts by crystals. To date no problems have been experienced. Greenock refinery has also had mid bearings fitted to their magma mingler which have lasted for three years without problems.
6. Hanger bearings - Screw conveyor hanger bearings were tested at Redpath Sugars in Toronto, Canada. However, ingress of sugar meant that the Rotalon bearings of the conventional design lasted only a few months. Phenolic resin bearings are now being used and a lifetime of six months is being achieved. The new submersible bearing has not, so far, been tried in dry applications of this type.
7. Gear pinions - British Sugar at Bury St. Edmunds installed last August a Rotalon gear pinion on their granulator/conditioner. The pinion is 17.5" diameter, it has a 6" face width and 20 teeth and has replaced cast steel. So far a reduction in lubrication and wear has been achieved on both the pinion and gear ring.



## DEVELOPMENTS

A number of new applications will be tried in the coming campaigns:

- 1) Trash plates at Kilombero Factory, Tanzania and Frome factory, Jamaica.
- 2) Coupling box inserts at Kenana factory in the Sudan.
- 3) Top half top roller bearings at Frome factory, Jamaica and Felixton factory, South Africa.
- 4) Raw sugar trash scrapers at Tate & Lyle's Thames Refinery, London.
- 5) The rotor and valve of the Smith Mirrlees Rotapump at the Allscott factory of British Sugar PLC.
- 6) Shredder hammer bushes at Hippo Valley, Zimbabwe and Fazal sugar mill, Pakistan.
- 7) Tyres for all the support rollers on the path rings at Greenock refinery, Scotland. This application is proved in other industries where both wear and noise are substantially reduced.

When tramp iron enters a mill serious damage generally occurs to the cast iron discharge tips on the 1st and 2nd mills. At both Nakambala and Raceland the Rotalon scraper tips, because of their flexibility, only had minor tooth damage while the other cast iron scraper in the tandem had to be replaced. Repair kits of a special superglue with dowel pins are being tested in the new campaign to strengthen repaired teeth.

As a monomer casting process requires steel molds, a standard profile of Rotalon scraper tip has been developed which will fit into the key dimensions supplied by the client, i.e. the distance from the support plate to the tip of the teeth, the tooth profile and the included angle. This ensures that the presentation of the tip to the roller grooving remains the same with only the profile or curvature being changed, which does not affect the efficiency of the mill.

Smith Mirrlees, will, therefore, be offering a standard profile scraper tip, at reduced cost, as an alternative to duplicating the profile detailed on the clients drawing.

Another area under current test is the capability of Rotalon to operate successfully in certain applications as a dry bearing, and for heavier duty applications to replace grease, or oil lubrication with water. If this is successful in top half top roller bearing trials this year, then the tandem of the future could be running with clean cold water lubrication instead of traditional heavy mill grease or oil.

## CONCLUSIONS

Several years of extensive trials have established Rotalon as a most suitable alternative material for many sugar industry applications. It matches and usually surpasses the wear rate of the traditional materials such as brass, steel and iron. More importantly, it substantially reduces wear on mating surfaces such as mill rollers and screens, it is less than a sixth of the weight making handling much easier and there are no corrosion problems.

Finally, its cost based on European manufacture is the same, component for component, as iron, approximately 10% less than steel, and less than half of gunmetal, brass or bronze. It can also be airfreighted to most parts of the world for less than conventional material sea freight charges.

Rotalon forms part of the trend in the forward looking engineering industries to move from traditional metals to alternatives, particularly plastics. Cost savings, improved performance and ease of handling have meant that polythene PVC, polycarbonate and carbon fibres are now commonly used in factories. Smith Mirrlees is integrating all these materials in our new designs and this growing trend will, no doubt, continue.



We have every confidence in the new applications being tried with Rotalon, and with the cooperation of factory management around the world we have demonstrated that a technical barrier has been broken with a new era of wear resistant materials.

#### ACKNOWLEDGEMENTS

We would like to thank all those factories who have helped us test Rotalon in its many applications. We would particularly like to thank those factories where teething problems were encountered and where their practical experience and assistance enabled us to quickly find solutions.

## MOTHER LIQUOR PURITY CHANGES IN LOW GRADE STRIKES

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### ABSTRACT

The control of vacuum pans via supersaturation requires a knowledge of the purity of the mother liquor. Massecuite and molasses samples obtained during C strikes have been analyzed. The results of this study together with calculation of crystal content and crystal growth rate are presented. The effect of changes in mother liquor purity on supersaturation and variations in massecuite consistency are discussed. A material balance is used to determine changes in purity expected and a mother liquor height profile is derived which agrees closely with experimental data.

### INTRODUCTION

Samples of massecuite from a C pan were extracted, at periodic intervals, during the boiling of low grade strikes. These samples were subdivided equally, one half being retained while the other half was purged in a small centrifugal to obtain molasses samples. Approximately seven samples per strike were obtained and data from 12 strikes were available.

The control of vacuum pans is dependent on the reliability and stability of measurements made. Furthermore the range of sensing systems available provides a wide latitude for selection of control systems.

Conductivity as a means of pan control has been described by Radford and Cox (1), Rein (2) and Wright (4), but does not appear to have the repeatability under local conditions. Consistency or viscosity has become popular in the last few years, but as is shown, it has limited applicability above specific massecuite Brix. The high dextran contents which sometimes occur in Louisiana, Texas and Florida also cause serious discrepancies in consistency measurements.

The supersaturation of a liquor can be calculated if the following parameters are known:

1. Massecuite temperature
2. Absolute pressure
3. Liquor purity

While the first two can readily be measured, purity values during a strike are not normally known.

By using a side chamber and a subsidiary vacuum pump (Figure 1) samples of massecuite could be withdrawn from the pan and their properties analyzed. Trends in molasses purity were obtained and a theoretical mass balance was used to determine the validity of these profiles.

The linearity which is shown for purity with massecuite volume, provides a reliable algorithm for determining purity changes during the strike. This algorithm could therefore be used along with temperature and pressure to determine liquor supersaturation and hence provide a suitable control function.

### Experimental studies

Molasses and massecuite samples extracted from the pan during several strikes were analyzed to give Brix and apparent purity using standard laboratory procedures.

Typical molasses apparent purity profiles are shown in Figure 2. These trends are characterized by a rapid drop during the first hour and a slower decrease during the remainder of the strike. This type of profile is to be expected since the footing purity is significantly higher than the feed purity. There is a great deal of scatter between individual profiles which is caused as much by boiling practices as differences in material purities.

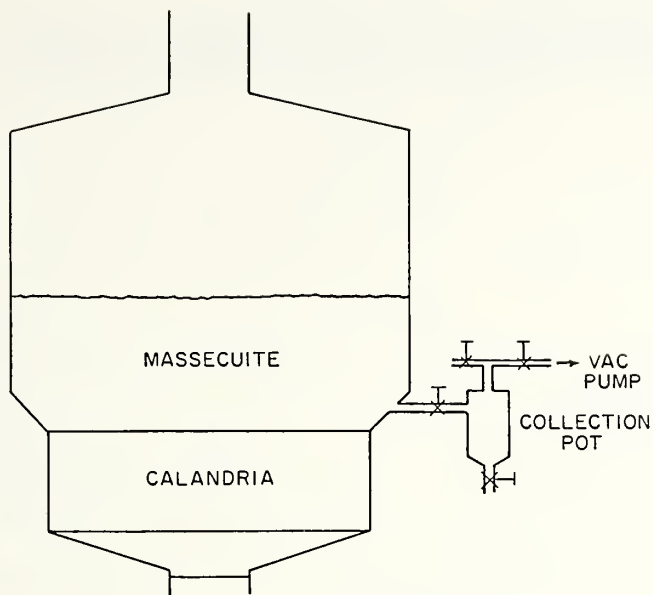


Figure 1. Diagram of sampling system.

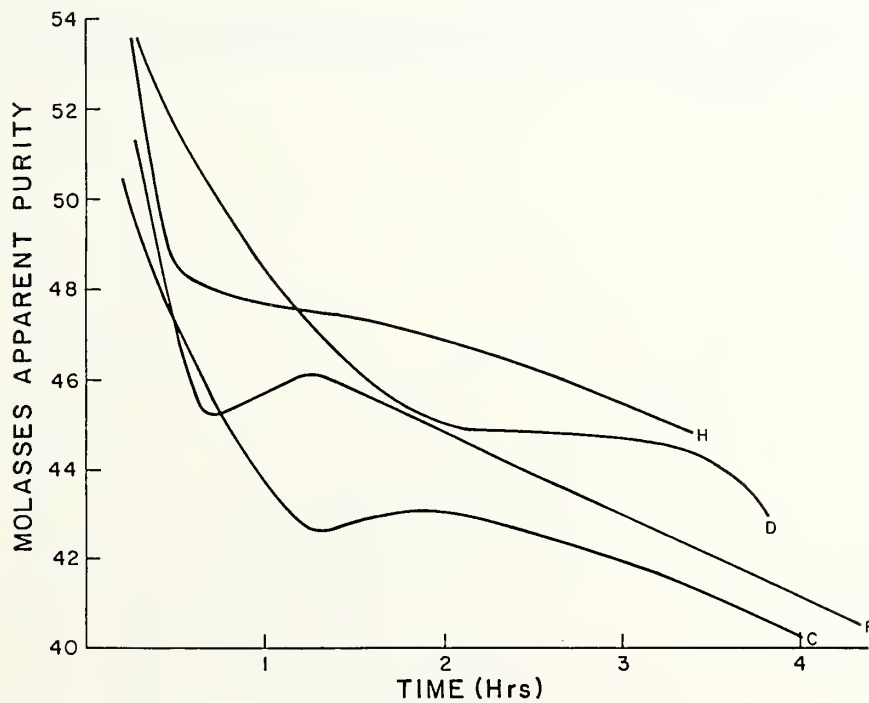


Figure 2. Typical molasses purity profiles.

Similar trends are shown in Figure 3 for massecuite purities. These show smaller fluctuations but purity differences of 4-5 points between strikes are still noticeable.

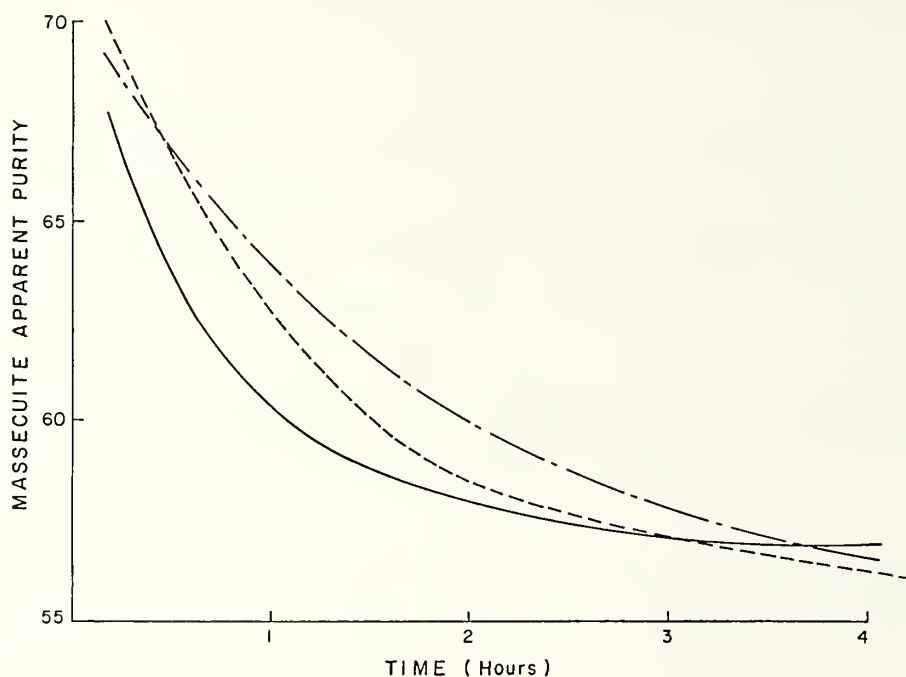


Figure 3. Massecuite purity profiles.

An average molasses purity profile has been determined for all the data available and is shown in Figure 4, where a relatively smooth trend is apparent but with considerable associated error.

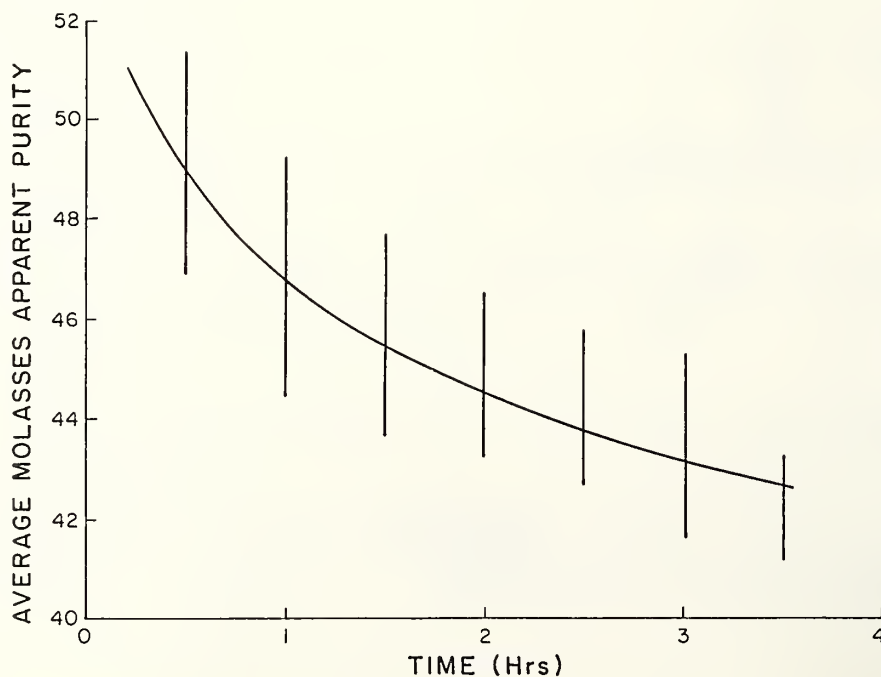


Figure 4. Average molasses purity profile.



Since both footing purity and B molasses (feed) purities differ between strikes, the errors involved can be reduced by considering purity differences. Figure 5 shows the difference in purity between feedstock (B molasses) and mother liquor. This plot exhibits a smooth trend with errors much less than seen earlier for the average purity profile.

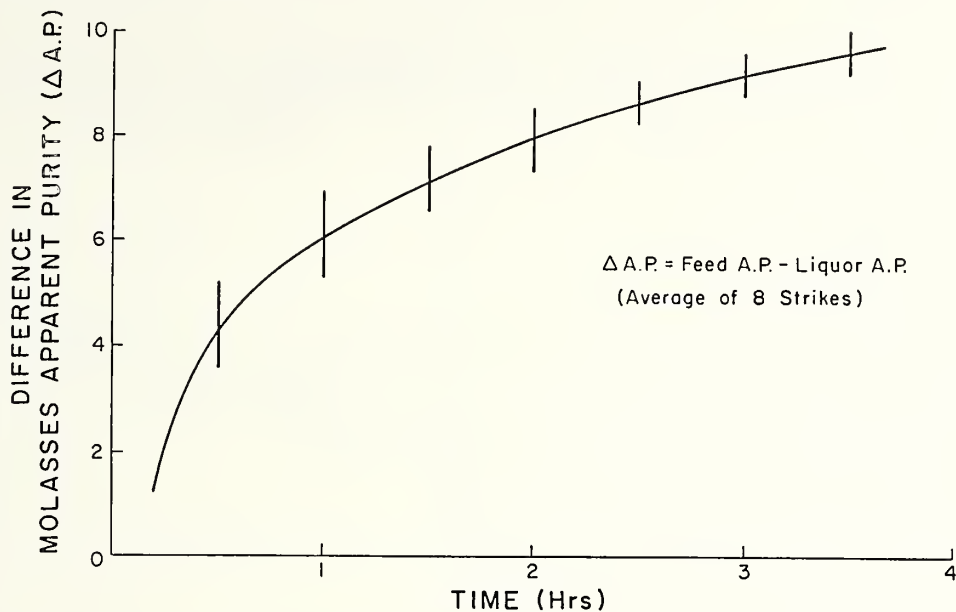


Figure 5. Variation of molasses purity difference.

The trends shown above have been analyzed as a function of time, but in general strike times can vary considerably due to material differences and boiling conditions. Figure 6 shows the volume in the pan as a function of time and this exhibits a trend similar to that for the purity difference as illustrated by Figure 5.

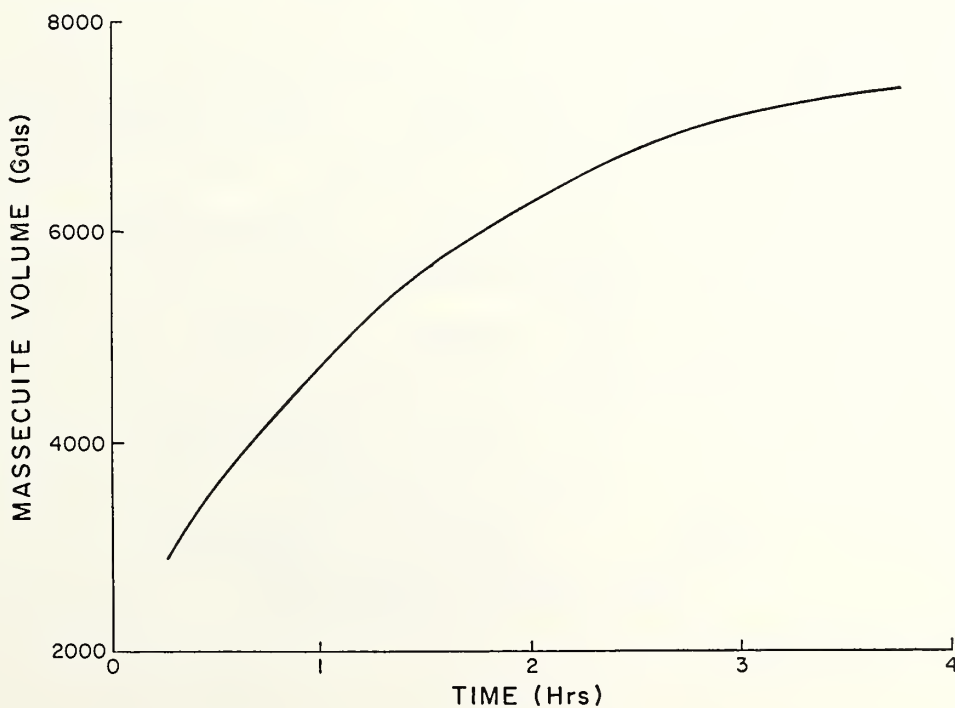


Figure 6. Massecuite volume as a function of time.

Normal boiling procedures are to pull in a footing (grain to about 1/3 of the pan volume and to pull it together while slowly admitting B molasses and keeping the level constant. When the footing has been established, the pan is put on a control system to admit feed at a specific rate determined by the required supersaturation.

If the volume of the pan above the footing level is plotted as a function of purity difference, (feed liquor - pan molasses purity), as in Figure 7, then a straight line relationship between the two parameter is observed. This type of profile therefore could be used as an algorithm to determine liquor purity providing the height in the pan is known.

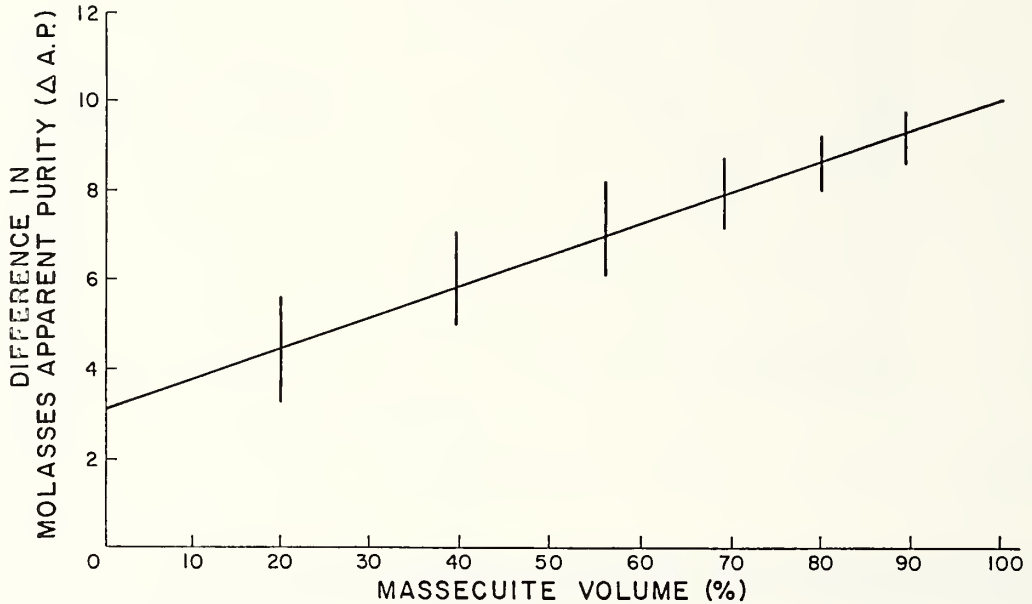


Figure 7. Difference in purity as a function of volume in pan.

#### Theoretical analysis

A mass balance analysis of the material in the pan can be carried out as shown in Figure 8 where quantities are expressed in mass, and apparent purities in fractions.

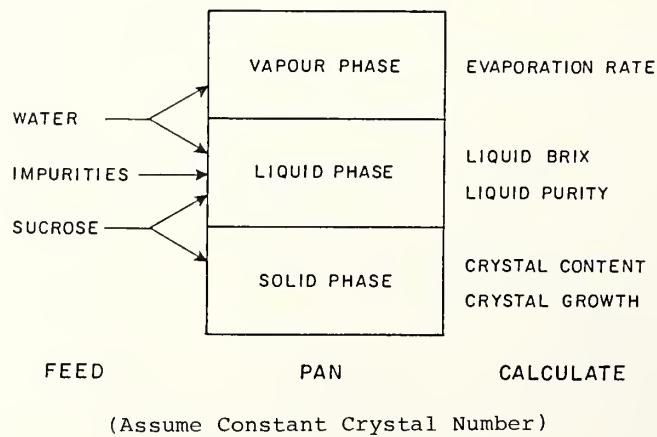


Figure 8. Mass balance.

The initial footing in the pan has the following components by mass:

Total sucrose,  $S_O$

Total impurities,  $I_O$

Crystal sucrose,  $C_O$

Water,  $W_O$

Hence massecuite purity is  $S/(S + I) = P$  (fraction)

Molasses purity is  $(S_O - C_O)/(I_O + S_O - C_O) = P_{mO}$

Massecuite Brix is  $(S_O + I_O)/(S_O + I_O + W_O) = B_O$

Molasses Brix is  $(S_O + I_O - C_O)/(S_O + I_O - C_O + W_O) = B_{mO}$

Crystal content as % solids is  $C_O/(S_O + I_O)$

Consider a feed material of the following composition by mass:

Sucrose content  $S_F$

Impurity  $I_F$

Water content  $W_F$

Hence feed purity is  $S_F/(S_F + I_F) = P_F$

Feed Brix is  $(S_F + I_F)/(S_F + I_F + W_F) = B_F$

The growth of crystal can be determined by the growth rate  $x$  measured in solids/unit time where  $x$  is the total increase in crystalline sucrose in lb/min.

The effect of adding feed to the pan can be determined by analyzing the solids balance alone (assuming all impurities remain in liquid phase).

1. Increase in sucrose in pan

$$\int_0^T F \cdot P_F dt$$

where  $F$  is the feed rate of solids in lb/min

2. Increase in impurities in pan

$$\int_0^T (1 - P_F) F dt$$

3. Increase in crystal weight in pan

$$\int_0^T x dt$$

Thus at any time  $T$  after footing has been taken into the pan the mass balance equations are

Sucrose in pan

$$S_O + \int_0^T F \cdot P_F dt$$

Impurities in pan

$$I_O + \int_0^T F(1 - P_F) dt$$

Crystals in pan

$$C_O + \int_0^T x dt$$

The purity of the massecuite and molasses can thus be determined from these equations.

$$\text{For the Massecuite } P_{\text{mass}} = \frac{\text{Total sucrose}}{\text{Total solids}}$$

$$\text{Molasses Purity } P_{\text{mol}} = \frac{\text{Sucrose in solution}}{\text{Solids in solution}}$$

Hence  $P_{\text{mass}} =$

$$\frac{S_0 + \int_0^T F \cdot P_F dt}{S_0 + \int_0^T F P_F dt + I_0 + \int_0^T F(1-P_F) dt}$$

Now sucrose in solution is given by

Total sucrose - Crystallized sucrose

$$S_0 + \int_0^T F P_F dt - C_0 - \int_0^T X dt$$

Total solids in solution is given by

Total solids - Crystallized sucrose

$$S_0 + I_0 + \int_0^T F dt - C_0 - \int_0^T X dt$$

Hence liquor purity is

$$\frac{S_0 - \int_0^T F P_F dt - C_0 - \int_0^T X dt}{S_0 + I_0 - C_0 + \int_0^T (F - X) dt}$$

This expression can be used in conjunction with either feed or footing purities to determine the purity difference, (feed purity - pan molasses purity) as a function of volume in the pan.

The ability to predict the purity is dependent on knowledge of the crystal growth rate.

Growth rates are expressed as the increase in linear dimension of the crystal, e.g. microns/min. Since the initial size and number of crystals are unknown this approach cannot be used in this instance.

The theoretical model has been used to determine liquor purity profiles during low grade strikes by assuming specific crystal growth rates in the pan.

Figure 9 shows the theoretical predictions of change in liquor purity with respect to feed purity. This shows a very close resemblance to the experimental data of Figure 8.

The discrepancies which exist are relatively small and would not seriously affect the value of supersaturation calculated. These differences are caused by the use of apparent purities rather than true sucrose.



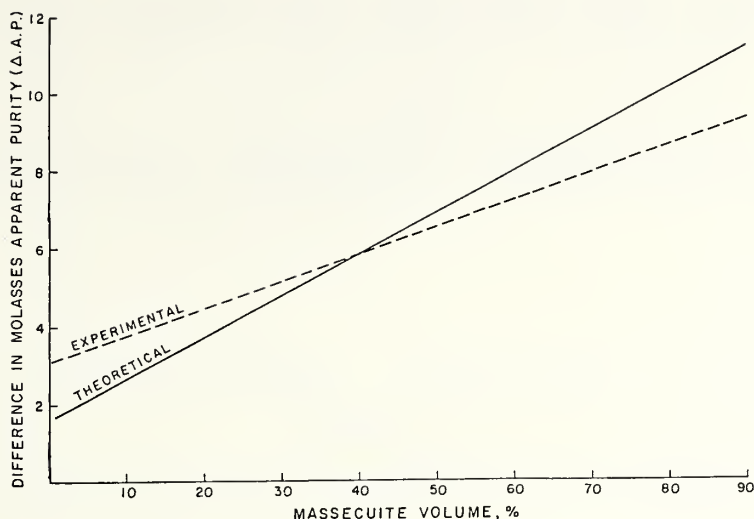


Figure 9. Theoretical difference in purity as a function of massecuite volume.

#### Consistency of massecuite

During the last few years, the use of a viscosity measurement has become increasingly popular in the U.S. cane industry. These sensors are either specially designed consistency monitors or make use of the power consumption of the stirrer fitted to the pan.

Figure 10 shows typical massecuite Brix - stirrer power trends for some of the strikes monitored. At low Brix values below 92, there is a reasonably linear relationship between Brix and consistency. However above 92 there is no such trend.

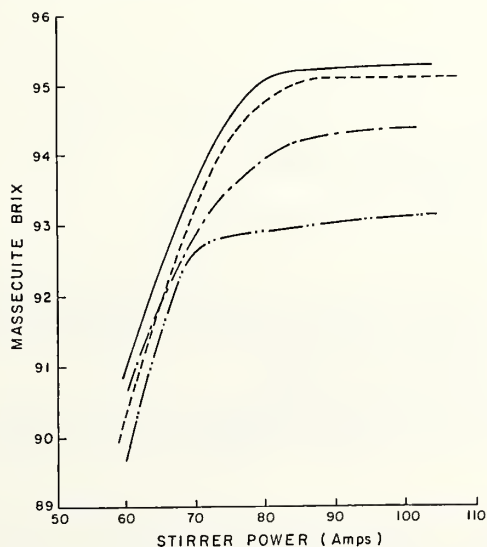


Figure 10. Stirrer power vs. massecuite Brix.

The massecuite Brix represents the total effect on viscosity of all solids content in the pan and hence should show a good correlation with consistency. Variation in the solids content of the mother liquor as well as the massecuite temperature will obviously play an important role in determining the overall viscosity.

The effect of molasses Brix on consistency is shown in Figure 11 and clearly there is no definitive correlation as would be expected. The use of consistency is further complicated by the presence of polysaccharides, notably dextran, which, when present even in small quantities, can noticeably increase the viscosity of the massecuite.

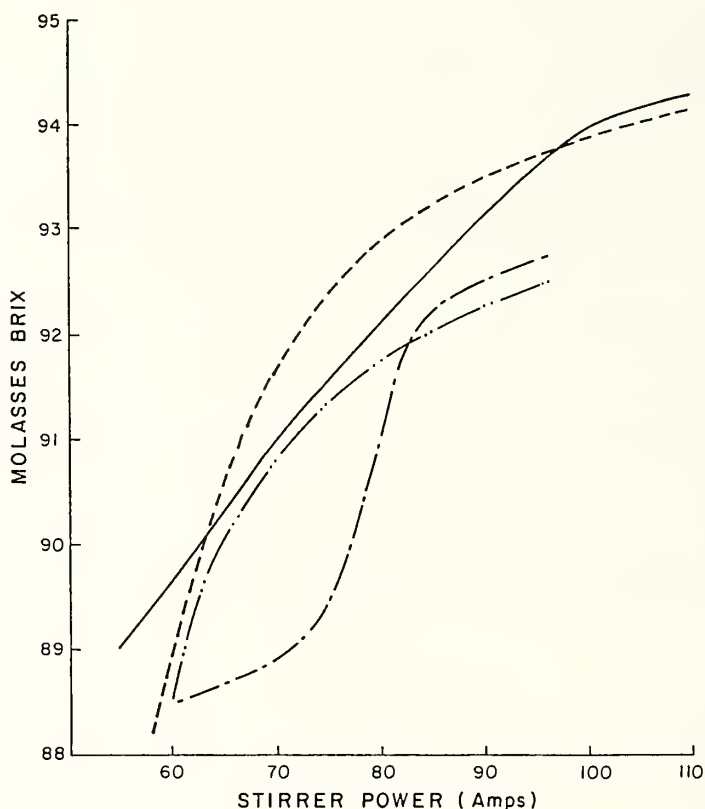


Figure 11. Stirrer power as a function of molasses Brix.

Recent work by Stein and Keenlside (3) has indicated the effects of massecuite properties on the torque in cooling crystallizers and indicates that small changes in temperature, about 5°F, can cause decreases in viscous effects by about 20%. Greater changes however are evident with liquor Brix where one point change can alter the torque (viscosity) by as much as 50%.

This work also indicates that the relationships between torque, crystal content, temperature and liquor Brix are nonlinear and hence are not ideal for control purposes.

#### Crystal growth

The analyses of purity changes have been performed using crystal growth data obtained during these studies. Using an apparent purity and crystal content by solids, mass growth rate for these studies has been calculated. This data is plotted against massecuite Brix as shown in Figure 12. This clearly shows a reduction in mass growth rate with Brix of the massecuite while Figure 13 indicates the effect of molasses Brix on growth rate.

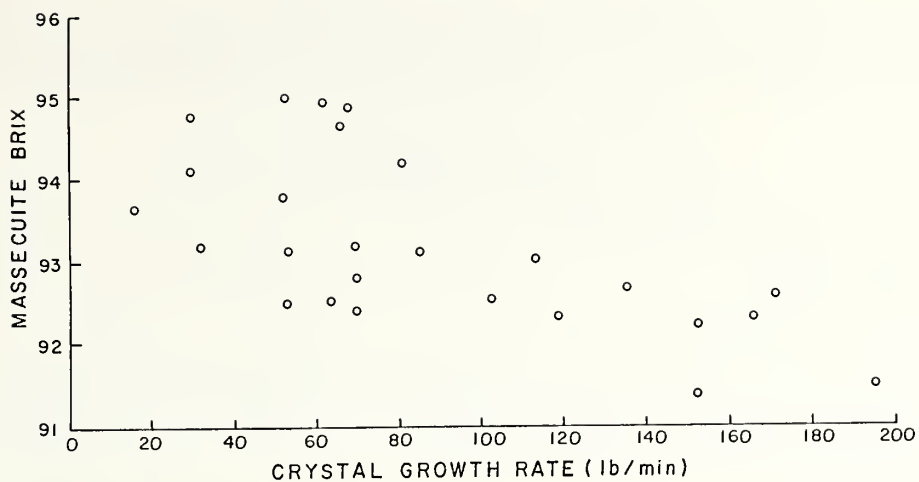


Figure 12. Crystal growth rate (solids) as a function of massecuite Brix.

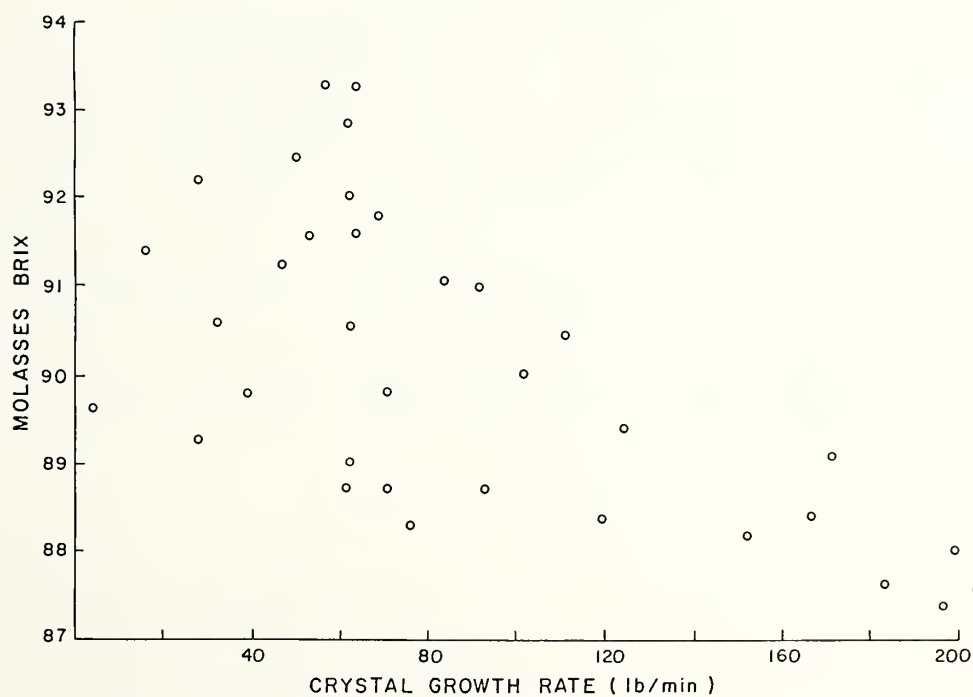


Figure 13. Crystal growth rate as a function of molasses Brix.

In all these instances, no account has been taken of crystal number and size and this will affect the ability to extract sucrose from the mother liquor. Furthermore the conditions in the pan are not kept constant and hence this further complicates the factors determining crystal growth rate.

Estimates of growth rate have been determined from assuming crystal sizes typical of C massecuites. These values are in the range 0.25 to 0.65 $\mu$ /min. (determined as the total increase in linear dimension/minute).

The interpretation of the decrease in growth rate with Brix cannot be uniquely determined since the effect of viscosity also has to be taken into account. At the same time, however, the liquor purity is decreased and this clearly will determine the growth rate.

#### CONCLUSIONS

The trends of molasses purity in low grade strike have been investigated and are shown to be linear with massecuite volume.

If supersaturation is to be used as the controlling parameter for vacuum pan operation then this trend can be used as an algorithm in order to calculate supersaturation.

The variations of consistency with both massecuite and molasses Brix are basically random and appear to be of little use as a means of control. The present program is to be expanded to analyze both A and B strikes in the same manner as well as to investigate the applicability of supersaturation, consistency and conductivity to other materials.

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## SUPERSATURATION CONTROL IN PAN BOILING

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### ABSTRACT

Previous studies of automatic control for vacuum pans have separately used a range of measurements to control the feed to the pan. This paper presents the results of a study carried out during the 1986 Louisiana sugar crop to further develop the principles of automatic control of the pan, using a microprocessor based data logger and controller.

The preliminary data obtained indicates how the feed to the pan may be controlled and compares the response of various parameters as well as showing the effects of automatic control versus manual control.

The problems associated with automatic control and the need for further work is indicated.

### INTRODUCTION

Control of the operation of vacuum pan is required in order to obtain maximum crystal growth rate, without production of false grain throughout the strike. The supersaturation of the mother liquor is the ideal measurement, but unfortunately this cannot be measured directly. Measurements of other parameters, such as conductivity (2, 4, 9, 16, 17), Brix (11, 18), consistence (2, 7, 9, 13) and boiling point elevation (1, 4, 5, 13) have been used to infer or replace supersaturation. These measurements have certain advantages, but the major disadvantage is their non-repeatability with respect to the supersaturation.

A microprocessor has been installed in a vacuum pan at St. Mary Sugar Co-op, Jeanerette, to control the operation of the pan. A wide range of sensors was subsequently installed and used to obtain the status of the pan. These sensors were for temperature, pressure, Brix, consistency and conductivity.

The microprocessor was programmed to control the feed to the pan, based on the liquor supersaturation which was calculated from the massecuite temperature, absolute pan pressure and the mother liquor purity. The absolute pressure was controlled independently of the microprocessor used to calculate supersaturation.

### MATERIALS AND METHODS

#### Measurements

Figure 1 shows the schematic of the pan with the position of the sensors.

#### Pressure

An absolute pressure sensor was placed at the top of the pan. The range of the unit was 10 to 90 inches of water absolute.

#### Temperature

Four thermocouples were placed at different points in the downtake of the pan, and the microprocessor was programmed to average the four readings.

#### Brix

An on-line refractometer was used at the bottom of the pan to determine the Brix of the mother liquor and was calibrated to cover the range 75% to 95% dissolved solids.

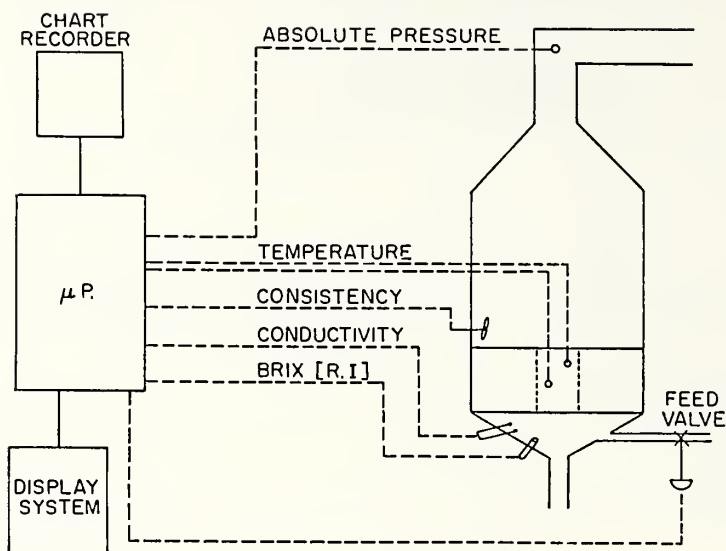


Figure 1. Pan monitoring diagram.

#### Consistency

A Ziegler consistency monitor was placed just below the calandria. The microprocessor was programmed to take the moving average of the last 20 values scanned. This was required to filter out the excessive noise in the system.

#### Conductivity

An electrical conductivity meter was placed at the bottom to the pan, the range measured being 0-100% of full scale. The conductivity is only a relative value as absolute values have no meaning. This signal was also filtered using the moving average of the last 20 values scanned.

#### Other methods

Other techniques for measuring massecuite Brix exist, but they are of no use for molasses properties and have not been considered, e.g. gamma ray density.

#### Supersaturation

The supersaturation used as the controlled variable, in this study, was determined from the data of Holven (8) as given by Gillett (5). Since supersaturation is used as a relative value, the effect of different solubility data is of little significance. A curve fitting procedure was used to produce an equation which calculates the supersaturation from the following values:

- a) absolute pressure
- b) massecuite temperature
- c) liquor purity

The absolute pressure and the massecuite temperature were available to the program as signal inputs from the transmitters located on the pan. The purity of the mother liquor was manually entered in the microprocessor by the operator.

The supersaturation formula is based on the boiling point rise of the mother liquor and can be calculated as shown below and can be calculated from a knowledge of parameters listed above.

Regression analyses of the data of Gillett have been used to determine the equations relating supersaturation to liquor temperature disolute pressure and liquor purity.

Boiling point rise at mother liquor saturation condition (BPE) is given by an equation of the form:

$$BPE = K_1 + K_2 \times K_3 \times AP^2 + (K_4 + K_5 \times AP + K_6 \times AP^2) \times TM$$

where  $K_1$  through  $K_6$  are constants

AP in liquor apparent purity

TM is massecuite temperatures °F.

The temperature at which water boils under the same pressure conditions as in the pan can be calculated as below:

$$TW = K_A + K_B / (K_C - \log_e (K_D \times Pr))$$

where  $K_A$  through  $K_D$  are constants

Pr is absolute pressure (" of Hg).

TW = boiling water temperature.

Hence supersaturation is:

$$S. Sat = (TM - TW) / BPE$$

Table 1 shows some supersaturation values calculated by the different supersaturation formulae available. These values were generated for a 70 purity liquor boiling at an absolute pressure of 5 inches of mercury.

Table 1. A comparison of different supersaturation formulas.

Temp. °F	SSG	SSJ
149.0	0.84	0.94
150.8	0.92	1.04
152.6	1.01	1.14
154.4	1.09	1.23
156.2	1.18	1.32
158.0	1.26	1.41
159.8	1.34	1.49
161.6	1.41	1.58
163.4	1.49	1.66
165.2	1.56	1.74
167.0	1.64	1.82

Purity = 70.0; Pressure = 5" of Hg absolute

SSG = A straight regression equation correlated from the actual data given in literature (5). These correlations were used in the on-line calculation of saturation conditions.

SSJ = A partial correlation based on the boiling point rise at saturation as given by Gillett (5).

## RESULTS

During the 1986 crop, numerous runs of the grain strike were monitored. The feed used was A molasses with a typical purity of between 72-74.

Figure 2 shows the trend of the three most important variables, i.e., pressure, temperature and supersaturation, for manual operation.

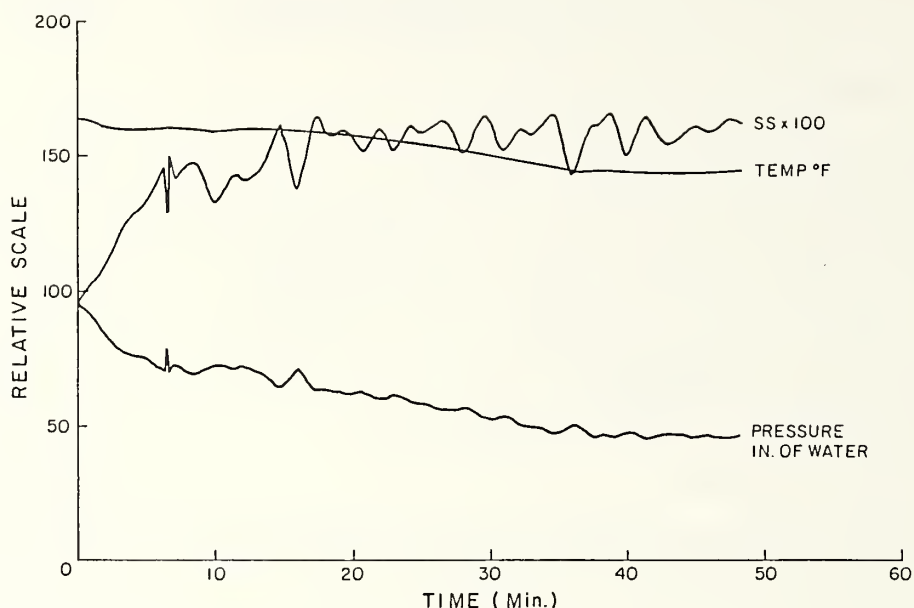


Figure 2. Grain strike data record (manual control).

Under these conditions, the supersaturation oscillates due to the action of the pan boiler. This is mainly caused by the operator making frequent adjustments to the manual feed valve, to maintain the desired conditions. By frequently over diluting the pan with excess feed, thereby reducing supersaturation, the operator slows down the crystallization rate. To compensate for this there is a period of rapid increase in the supersaturation, thereby running the risk of false grain formation.

Figure 3 shows the trend of pressure, temperature and supersaturation under manual and automatic control.

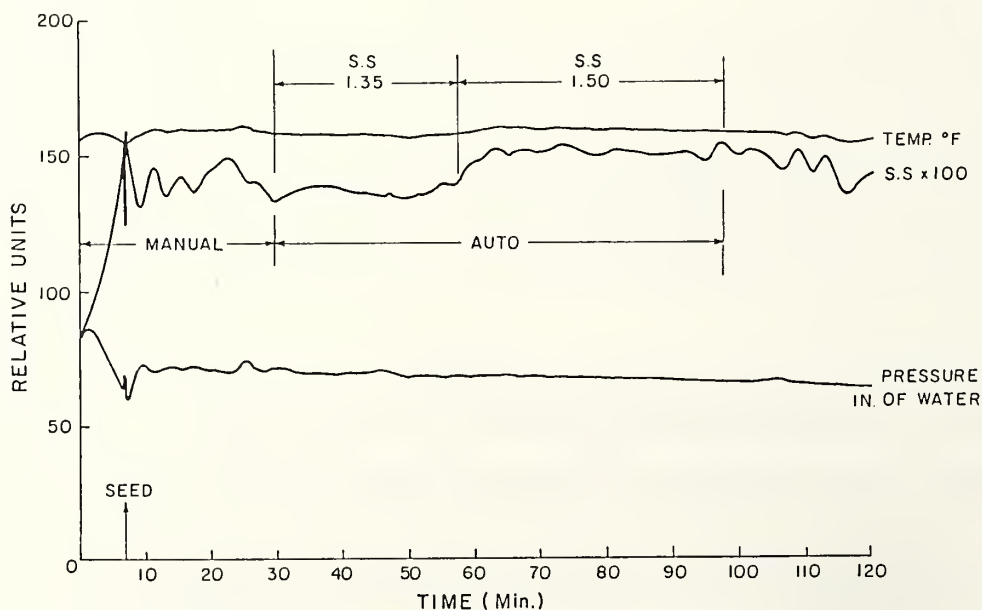


Figure 3. Grain strike data record (manual and auto).



Under automatic control, the supersaturation is maintained within a much narrower band around the desired level. This reduces the operator intervention for the major part of the strike and thus, tighter control can be achieved.

The controller scans the process every few seconds to detect any difference between the desired supersaturation and the actual supersaturation. Thus the controller action is taken every few seconds. This avoids the need for drastic valve action to bring the pan condition to the desired level. By keeping the changes in valve position small, the controller is also able to avoid wide perturbations in the absolute pressure.

The seeding point could be determined using the supersaturation number. In all strikes, it was repeatable. The strikes were always seeded within a supersaturation range of 1.4 to 1.5.

Figure 4 shows a typical trend of the monitored variables, as the strike progressed. It can be easily seen that the absolute pressure gradually decreases, but with inherent oscillations, and that the temperature follows the pressure. The conductivity is almost flat for the entire duration of the strike, while Brix increased till the seeding point and then was almost constant. Only supersaturation shows sufficient applicability.

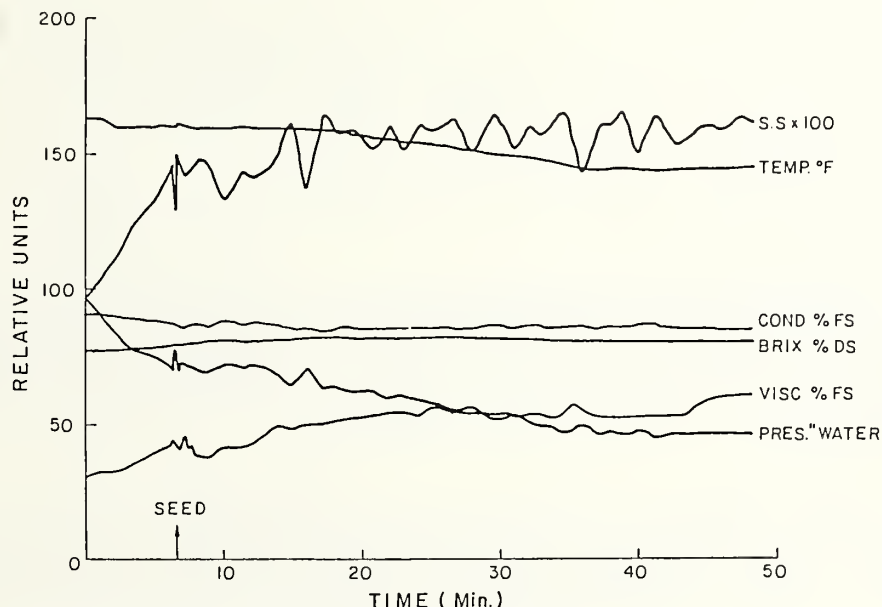


Figure 4. Grain strike data record (manual control)

The main problem encountered was the absolute pressure as it was not possible to hold it constant. As the strike progressed, the absolute pressure gradually decreased and oscillated around a mean value. Since the pressure controls the temperature of the boiling massecuite inside the pan, it continuously altered the state of the pan.

The pan was equipped with a pneumatic pressure controller but its response could not eliminate the oscillations in the absolute pressure values.

#### Consistency

The Ziegler consistency monitor was sufficiently sensitive to the massecuite viscosity, but its use as the controlled variable is debatable as there was excessive signal noise in the system and the relationship between viscosity and the temperature of the medium is unknown. Since in the present system, pressure was not a constant, the temperature fluctuated and hence it was not possible to obtain repeatable values of consistency for the same supersaturation values. Figure 5 shows the relationship between consistency and the supersaturation when supersaturation is the controlled parameter.

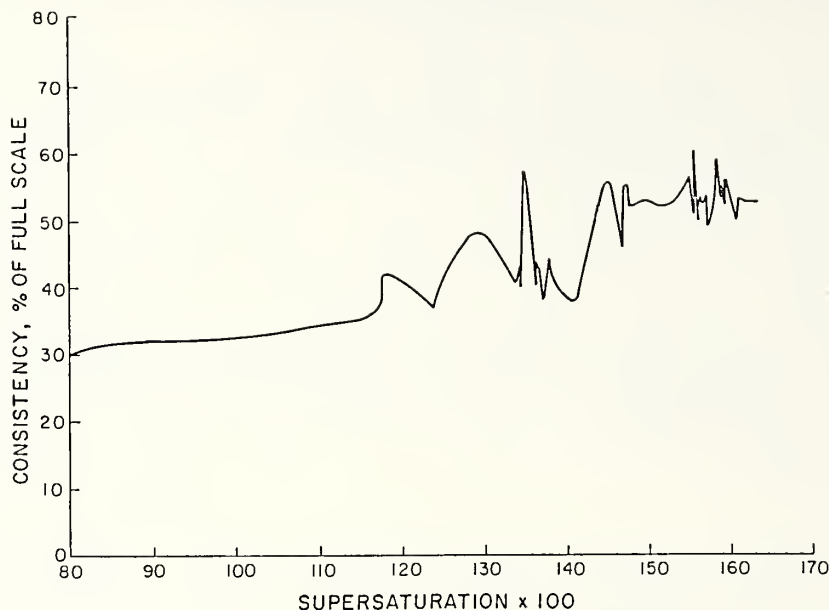


Figure 5. Comparison between consistency and supersaturation.

#### Conductivity

The electrical conductivity installed did not have sufficient sensitivity for normal conditions. The trend showed little fluctuation, though it did show a slight correlation with the absolute pressure. Thus, it was rejected as a controlled variable, under these conditions. High frequency conductivity as developed by Reichard and Vidler (12) has been used with greater sensitivity and is presently being considered.

#### Brix

The on-line refractometer Brix monitor was a good measurement until the seeding point. It was fairly repeatable in the different runs, but after the seeding there is no noticeable change in the Brix value. Thus it was suitable to infer the seeding point but not to control the feed to the pan after this time. Limiting the range of the instrument is one method which may be a solution to improving its value for seeding.

#### Supersaturation

Supersaturation appears to be the most reliable of all the measured variables. As with other methods, signal averaging on all measurements, e.g., pressure, temperature, were necessary to compensate for random fluctuations. It was found to be sensitive and repeatable.

#### Control theory

The microprocessor is a very advanced tool through which it is possible to achieve various kinds of control such as on/off control, PID feedback control or any other advanced digital control.

On/off control was initially ruled out since this results in wide oscillations of the controlled variable around the desired value, but work by Hashimoto, et al. (6) suggests it may be a suitable basis for control. Advanced control strategies were also ruled out as the tuning of a control loop using such systems as Dahlin controllers is very different from the simple and familiar tuning of a PID loop. As most plant personnel are familiar with the PID controller there was no advantage to be obtained by using an advanced strategy.

A PID loop consists of three parts. The proportional, the integral and the derivative part and hence the name PID. A full discussion of the control theory, the PID loop and its tuning methods is available in many excellent texts and is not repeated here (13, 15).

The analog form of the PID loop equation is as follows:

$\mu_0$  = controller bias output in %

$\mu$  = present output of controller in %

$k$  = controller gain in %

$e$  = present error

$$\mu = \mu_0 + k[e + \frac{1}{T_R} \int_0^t e dt + T_D \frac{de}{dt}]$$

$T_R$  = reset time in sec.

$T_D$  = derivative time in sec.

Since a digital computer scans the process at fixed sampling rate, the analog form cannot be used. The digital form of the PID loop equation is as follows:

$$\mu_n = \mu_0 + k[e_n \frac{T_S}{T_R} \sum_{i=0}^n e_i + \frac{T_D}{T_S} (e_n - e_{n-1})]$$

$T_S$  = sampling time of controller

$n$  = at this sample

$n-1$  = at previous sample

This is widely known as the position form of the PID algorithm and while it is popular, it has certain computational problems hence the velocity form of the PID algorithm is preferred.

$$\mu_n = k[e_n - e_{n-1} + \frac{T_S}{T_R} e_n + \frac{T_D}{T_S} (e_n - 2e_{n-1} + e_{n-2})] \quad \mu_n = \mu_{n-1} + \mu_n$$

$n-2$  = value 2 samples ago

$\Delta$  = change from previous value

This is the equation programmed in the microprocessor.

#### CONCLUSIONS

Various parameters were measured for the grain strike and all were not sufficiently sensitive to be used as the controlled variable for the feed control. Supersaturation, calculated using the pressure and the temperature, was found to be the most suitable and was used to control the feed. It eliminated the need of frequent operator supervision and was useful in successfully predicting the seeding point.

Lack of sensitivity in the measurement of Brix, consistency and conductivity with respect to determining the graining point still requires further study and their use for this and other strikes in the Louisiana industry has not been discarded.

The supersaturation number, as calculated by the formula, uses a fixed purity of the mother liquor as the basis of the calculation. In fact, as the strike progresses, the purity of the mother liquor is going to drop. Further work is needed to compensate for this purity drop and to determine the purity profile with respect to the time or the level of the pan.

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POTENTIAL USES AND ASSOCIATED BENEFITS OF DEXTRANASE  
ENZYME IN THE RAW SUGAR MILL

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ABSTRACT

Several commercial dextranase enzyme preparations were compared in a series of laboratory tests wherein enzyme rates, incubation times, and incubation temperatures were varied. The relative merits of several alternative points of application including mixed juice, the final effect of the evaporator, and the syrup storage tank are discussed and evaluated on the basis of enzyme required, reaction time and temperature necessary, and potential benefit to be realized.

INTRODUCTION

The problems attributed to dextran contamination in the raw sugar mill are numerous and include slowed crystallization, elongated sugar crystals, poor centrifugation, increased molasses purities, poor quality sugar, slow mud settling rates, and poor clarification. In short, the entire sugar-making operation is affected dramatically. Unfortunately, the effects of dextran, low purity juices, and generally poor cane are difficult to separate; dextran therefore has probably been given less attention than it deserves.

As dextran is largely a field and transportation problem if mill sanitation is reasonably good, the focus of efforts to reduce dextran must be in those operations. However, after the dextran has already reached the factory, the operating personnel must deal with dextran's effects on the milling and fabrication operations. One potentially very effective tool for reducing dextran levels is the enzyme dextranase. Like all enzymes, it is substrate-specific, in this case for dextran, and it behaves as a catalyst, not being consumed in the process. Because of the latter characteristic, only very low levels of enzyme are required to destroy relatively large amounts of dextran. Typical dose rates reported in the literature for various enzymes are 2-100 ppm based on solids in the stream being treated. Like other biological catalysts, dextranases have an optimum temperature and pH for highest activity. Likewise, the Brix of the treated material exerts an effect on the activity of dextranase. If one must use a dextranase under conditions different in any way from its optima, more enzyme must be used to achieve the same results.

Dextranase has been used commercially in Australia and several other countries for a number of years, but it has not been available to the U. S. industry because it has no Food and Drug Administration (FDA) clearance for food uses. At the present time, at least two products have been submitted to the FDA for clearance as sugar factory additives, and it is probable that the enzyme will be available for our use in the near future. For this reason, we have examined several available dextranases for their effect on dextrans encountered in Florida factory streams. Research reported in the literature (7) indicates that the various cane-producing areas may produce dextrans which differ in their susceptibility to hydrolysis by the enzyme, so data of this type are a necessary prerequisite to successful factory use of this enzyme.

METHODS AND MATERIALS

Enzyme preparations were commercial products supplied by NOVO Industri (Bagsvaerd, Denmark), Miles Laboratories (Elkhart, IN), Amano International Enzyme Co. (Troy, VA), Enzyme Development Corporation (New York, NY), and Tate and Lyle U.S.A. (Coral Gables, FL).

Synthetic juices used for preliminary work consisted of 15% (w/v) sucrose, 0.5% (w/v) each of glucose and fructose, and various concentrations either of T40 or T2000 dextran (Pharmacia). In addition to the synthetic juices, a heavily contaminated crusher juice was produced by overnight incubation at room temperature. The juice was found to contain 11000 ppm (based on Brix) of dextran at the end of this period. This juice was divided into 100 portions of 100 ml each and stored

at -20°C until used. Prior to use, samples were quickly thawed in a 45°C water bath with frequent shaking to prevent localized overheating. This procedure was shown to produce no dextran. For syrup tests, a naturally contaminated sample with a dextran content of 8000 ppm on Brix was used. All syrups were diluted with three volumes of distilled water prior to dextran testing.

Dextranases were added as a 3000 ppm (w/v) stock solution, and reaction mixtures were incubated in thermostatted water baths. The reactions were stopped by the addition of 6 ml of 10% (w/v) trichloroacetic acid to 35 ml of reaction mixture, and dextran was quantitated before and after the reaction using the alcohol haze method (1). This method is based on the original CSR method used for over 20 years by the Australian sugar industry. The results of this determination have been found to be strongly correlated with processing problems. The results of the haze test should however be viewed only as relative comparisons for a number of reasons. The haze-forming potential of very low molecular weight dextrans is much less than that of high molecular weights. While the native dextrans are normally high molecular weight, the enzymes break them down into successively smaller fragments which have lower haze-forming potentials. This tends to cause an underestimation of dextran actually present in the enzyme-treated materials. On the other hand, the haze method is standardized using relatively low (40,000) molecular weight purified dextrans. Since the actual native material in juice is typically of much higher molecular weight than the standard, the haze result tends to overestimate ppm dextran originally present.

#### RESULTS AND DISCUSSION

The first tests were preliminary in nature and employed an enzyme (DN25-L)<sup>1</sup>/ marketed by Novo. This is a liquid material with a suggested application rate of 10-30 ppm based on juice volume and with preferred operating conditions of pH 5-6 and 50-60°C. Preliminary tests showed that the enzyme was very active against both low (40,000) and high (2,000,000) molecular weight dextrans. Next, tests were conducted to examine the effects of enzyme concentration, incubation temperature, and incubation time on a crusher juice containing about 3500 ppm (based on Brix) of native dextran. It was found (Table 1) that as little as 10 ppm (w/v) of enzyme provided essentially complete cleanup of the juice in 30 minutes at 55°C and the natural pH of the juice. Dropping the incubation temperature to 40°C did not affect the results at this relatively low level of dextran. In fact, just 5-10 minutes appeared sufficient to hydrolyze a large percentage of the dextran at this level of contamination.

Table 1. Effects of incubation time, incubation temperature, and enzyme concentration on the hydrolysis of native dextran in crusher juice. Nova DN25L enzyme.

Enzyme concentration (ppm w/v)	Incubation time (min)	Incubation temperature (C°)	Absorbance 720 (mn)
0	30	55	.897
	30	55	.030
	20	55	.077
	15	55	.094
	10	55	.147
	5	55	.285
10	30	40	.043
	30	55	.024
	20	55	
	15	55	
	10	55	
	5	55	
25	30	55	
	20	55	
	15	55	
	10	55	
	5	55	
	30	40	

Encouraged by these preliminary results, we proceeded with a more thorough investigation of several available dextranase products and to examine the literature to see what had been done elsewhere. We were able to obtain five different products at that time (1982) for comparative evaluations. These were Miles Laboratories' DL-2, Novo's DN25L, Enzyme Development Corporation's Enzeco Dextranase, Tate and Lyle's Talozyme D, and Amano's Sugarase. The five materials differed in claimed activity, price, and source organism.

<sup>1</sup>/Use of trade names in this report is for identification purposes only and does not constitute an endorsement.

The synthetic juices were used to determine the relative activity of the five products against purified dextrans. Data indicated that the Miles and EDC products were somewhat more active against the purified dextrans present than were the Amano, Tate and Lyle, and Novo products under the conditions of these experiments. With synthetic juices, 3 ppm of the former two products was about equivalent to 10-20 ppm of the latter three when the goal was complete cleanup of 1000 ppm dextran in 20 minutes at 40°C. Increasing the dextran to 10,000 ppm, a very high level, again indicated the same order of activity; i.e., 10-15 ppm of the Miles and EDC products was about equal to 50-70 ppm of the other three enzymes, all providing essentially complete cleanup in 20 minutes at 40°C. The molecular weight of the dextran did not appear to be a factor. Using these data, we proceeded to tests with heavily contaminated cane juice. It was found (Table 2) that 10 ppm of the more active Miles and EDC products provided 90% cleanup even at 40°C if allowed 30 minutes of incubation time. If the time was limited to just 15 minutes, about 6400 ppm of dextran was hydrolyzed. Reducing the rate to just 5 ppm, the same 15 minutes at 40°C resulted in destruction of 2200-2900 ppm of dextran. The other enzymes were less active, with both the Tate and Lyle and the Novo products appearing slightly less active than the Amano product. A rate of 10 ppm enzyme and an incubation period of 30 minutes at 50°C resulted in removal of 4700, 3600, and 6600 ppm of the dextran, respectively, with these products. It should be pointed out, however, that partial dextran removal may not produce corresponding improvements in subsequent processing (2).

Table 2. Relative activity of five commercial dextranases against native dextran in deteriorated crusher juice.

Product	Concentration (ppm, w/v)	Temperature(°C)	Time(min)	Dextran hydrolyzed (ppm on Brix)
Miles	10	50	30	10,605
	10	40	30	9,547
	10	40	15	6,169
	5	40	15	2,423
EDC	10	50	30	10,458
	10	40	30	9,386
	10	40	15	5,141
	5	40	15	3,598
Tate/Lyle	10	50	30	4,788
Novo	10	50	30	3,635
Amano	10	50	30	6,639

The point of enzyme addition is a problem in practice, as the necessary incubation time is probably not available in the milling process as it is run now. Large mixed juice tanks are inserted into the process in Australia to solve this problem. A further drawback to mixed juice application is the fact that the clarification process itself has been reported to remove a variable amount of dextran (2). Our own results (Table 3) support this argument. It therefore may be wasteful to treat contaminated material before its clarification. In addition, soil present in raw juice may contain enzyme inhibitors (4). Finally, the volumes of material to be treated are very large and can vary tremendously in dextran content over short spaces of time, little or no "averaging" having taken place this early in the processing (2). Another point of application suggested by one company (5) is the final effect of the evaporator system. This was found to be impractical in our situation due to the high temperatures reached there on a more or less routine basis. Mill data indicated that 180°F (82°C) was a likely temperature to be considered. Laboratory work (Table 4) showed that the enzyme activity is rapidly lost at this temperature, as little as five minutes' exposure producing a loss of 50% of the activity. The final point of enzyme addition considered was to the syrup. While the pH and Brix of the syrup are off the optimum, the volumes to be treated are much smaller, some cleanup has already been accomplished via the clarification process, and the necessary incubation time is at least potentially available. Syrups have been treated effectively in Australia (2) and in pilot tests at LSU (6).



Table 3. Effect of clarification process<sup>1/</sup> on juice dextran levels.

Dextran (ppm on Brix)		Dextran removal (%)
Crusher juice	Clarified juice	
4004	2420	39.6
1643	740	55.0
6922	2194	68.3

<sup>1/</sup> Process includes cold liming prior to juice heaters and the addition of an anionic polymer flocculant at the clarifier.

Table 4. Efficiency of dextranase exposed to temperature of 180°F for various periods<sup>1/</sup>.

180°F Exposure time (min) <sup>2/</sup>	Absorbance (720nm)
Control	.954
1	.204
5	.406
10	.918

<sup>1/</sup> Reaction conditions were 20 ppm (w/v) Miles dextranase, 150°F, and 30 min incubation time. Syrup was 60° Bx and contained 6,500 ppm (based on Bx) of high molecular weight (2,000,000) pure dextran.

<sup>2/</sup> Syrups were brought to 180°F prior to addition of dextranase, maintained for desired time, then brought rapidly to 150°F by immersion in ice water. After 30 min incubation at 150°F, enzyme was inactivated by 3 min in a boiling water bath.

For our tests, we used a syrup with a dextran level of about 8000 ppm, an extremely high level unlikely to be encountered in the mill but excellent for the purposes of these tests. Initial tests to fix the enzyme rate showed (Table 5) that about 100 ppm of the Miles product was needed to effect complete cleanup in 30 minutes at 150°F (65°C). However, 50 ppm or less would be a more normal requirement because of the very high dextran loading in this particular syrup as compared to a more realistic case which might be expected in the mill. This is made clearer by the data in Table 6 relating enzyme dosage to ppm dextran hydrolyzed. The 20-40 ppm range appears to be the most likely dose required. Finally, if more time could be made available (Table 7), complete cleanup of even this heavily contaminated syrup can be achieved in around 45 minutes at the 50 ppm rate.

Table 5. Effect of different rates of Miles dextranase on dextran content of a heavily contaminated syrup. 150°F, 30 minutes.

Dextranase rate (ppm, w/v)	Dextran remaining (ppm on Brix)
0	8,123
50	1,332
100	594
150	0
200	0



Table 6. Effect of lower levels of Miles dextranase on dextran content of a heavily contaminated syrup. 150°F, 30 minutes.

<u>Dextranase rate</u> (ppm, w/v)	<u>Dextran remaining (ppm on Brix)</u> <sup>1/</sup>
0	7426
20	5895
40	3052
60	2132
80	940
100	805

<sup>1/</sup> All data are the mean of two tests with each enzyme rate.

Table 7. Effect of increased reaction time on performance of 50 ppm Miles dextranase on syrup, 150°F.<sup>1/</sup>

<u>Time (min)</u>	<u>Dextran remaining (ppm on Brix)</u>
30	2,154
30	2,139
45	51
45	328
60	20
60	0

<sup>1/</sup> Initial dextran content of syrup was approximately 8,000 ppm based on Brix.

The conversion of these results to dollars and cents is of obvious interest (Table 8). For each 1000 TCD of capacity, a factory with a mixed juice extraction of 89.25% and a mixed juice Brix of 16.19 will produce about 241 T of 60° Bx syrup per day. Treating all of this syrup at 20 ppm (w/v) will require 3.4 kg per day of enzyme at a cost of \$204-272 depending upon the price per kg. The ranges quoted assume \$60-80/kg for the most active enzyme materials, with the lower activity materials expected to be somewhat cheaper. At the 40 ppm level, 6.8 kg of enzyme would be required at a cost of \$408-544. To put these costs in perspective, an improvement of 2 points in exhausted purity of final molasses is worth \$240 per day in additional sugar for each 1000 TCD of capacity. This type of improvement is a conservative estimate based on results in the literature (2,3) describing Australian trials performed after unexpected shutdowns necessitated grinding a large tonnage of very deteriorated cane. These workers observed as much as 4-9 points improvement in exhausted purity.

Table 8. Projected costs for treating syrup output of 1000 TCD factory with various rates of dextranase.<sup>1/</sup>

<u>Dextranase rates</u> (ppm, w/v)	<u>Dextranase required (kg)</u>	<u>Cost (\$/da)</u> <sup>2/</sup>
20	3.4	204-272
30	5.1	306-408
40	6.8	408-544
50	8.5	510-680

<sup>1/</sup> Assumes 241 T. of 60° Bx syrup.

<sup>2/</sup> Assumes \$60-80/kg.

The value of increased raw sugar quality depends on the dextran level being encountered. If sugar of 350 MAU is reduced below 250 MAU, the value is \$303 per day in a 1000 TCD factory with a 10.84% yield figure. If the sugar is 450 MAU without enzyme, the saving is \$694 per day. If the sugar is as bad as 550 MAU, the potential saving is \$1,171 per day. In addition, increases in boiling rate and crystallization speed, improvement in crystal shape and centrifugal performance, and prevention of boiling house blockages all must be considered. I would submit that the use of dextranase, while expensive, may still be economical at times when dextran-contaminated cane supplies cannot be avoided.

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## COLOR DETERMINATIONS ON RAW SUGARS - A METHOD COMPARISON

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### ABSTRACT

A survey of 149 Florida raw sugars from several mills and crop years was conducted to examine the relationship between ICUMSA Method 2 Color and the Method 4 (Modified) color incorporated into the New York Coffee, Sugar, and Cocoa Exchange's raw sugar Contract #14. Effects of small changes in the various steps of the affination procedure used to prepare sugars for color determinations were also determined. Finally, the economic consequences of substituting Method 4 (Modified) for Method 2 are outlined for sugars of low, average, and high color.

### INTRODUCTION

One of the principle functions of the sugar refining process is the removal of the amber-brown color of the raw sugars (3). The darker the sugar, the heavier the decolorizing load on the refinery and the higher the processing cost. Because of this fact, a color premium-penalty schedule has been a standard part of raw sugar contracts for some time. Unfortunately, the methods for quantitating raw sugar color have historically been a matter of personal taste. ICUMSA finally adopted seven methods on a tentative basis in 1958, added and dropped methods for several years, and finally settled in 1974 on one method for white sugar and two for darker products (7). This situation continued until the introduction of a third raw sugar method by Savannah Foods in 1984 (8). A comparison of the salient features of the three methods (Table 1) indicates that the most important differences are in the wavelength used for final absorbance measurements and in the pH at which the measurement is performed. The use of 560nm in the older Method 2 was based on work by Peters and Phelps (5) which showed 560nm to be the optical center of gravity of sugar colorants. However, because the use of instruments to measure the color was increasing, the higher absolute values of the absorbance at 420nm made that wavelength preferable for increased sensitivity (6). This was the basis for Method 4 of ICUMSA. Depending upon the literature cited, both 560nm and 420nm have been correlated with the visual color ratings of white sugar solutions (4,10,11).

Table 1. Pertinent features of ICUMSA Method 2, ICUMSA Method 4, and Savannah Method 4 (Modified) raw sugar color analyses.

Method 2	Method 4	Method 4 (Modified)
pH 7.0	pH 7.0	pH 8.5
560nm	420nm	420nm
Affined sample	Affined sample	Both raw and affined
no turbidity correction	no turbidity correction	turbidity correction
50° Bx	50° Bx	25° Bx (raw)
		50° Bx (affined)

In addition to wavelength, the pH is also an important factor in these measurements. While pH 7.0 was used for many years, the Savannah method, or Method 4 (Modified) as it was labelled, utilized a pH of 8.5, though critics were quick to point out that no finished refinery product had a pH anything like 8.5. The result of switching from pH 7.0 to pH 8.5 is obvious from consideration of Figure 1 (1). At both wavelengths, but especially at the 420nm wavelength, there is a dramatic increase in color associated with the increased pH. It is also apparent that the accuracy of the pH adjustment is critical to the accuracy and reproducibility of the color measurements due to the steep slope of the curves in the region of interest.

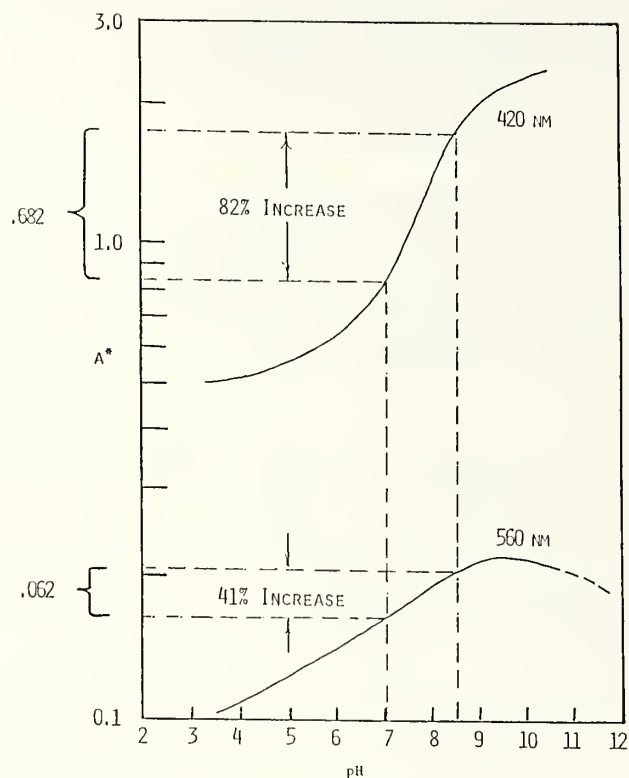


Figure 1. Typical pH-absorption curves at 420 and 560 nm.

#### METHODS AND MATERIALS

The actual equipment and manipulations involved in the determination of color are well specified. Affination is carried out by adding 380ml of 64° Bx granulated sugar syrup to 1000 grams of the raw sugar at a constant rate over a period of 4 1/2 minutes. The sugar is stirred gently using a commercial food mixer during the syrup addition and for one additional minute after the syrup addition is finished. The entire magma is next centrifuged at 3000 rpm for 2 minutes prior to drying. The dried sugar is dissolved at 50% solids in distilled water, filtered through either filter paper (Method 2) or glass fiber filter discs (Method 4 Modified), adjusted to the proper pH, and finally read at the proper wavelength in a 1cm optical glass cell against a distilled water blank. For Method 4 (Modified) only, the color of a 25% solution of the whole raw prior to affining is also determined.

#### RESULTS AND DISCUSSION

The effects of small variations in procedure on the color values of a typical sugar sample are shown in Table 2. Trials 2 and 3 are indicative of the degree of reproducibility expected from careful work. Three sources of variability examined in this study were the Brix of affination syrup, the syrup addition time, and the centrifugation time. While there were small effects due to these changes, the methods appear to be fairly forgiving of minor variations in procedure. Increasing the Brix of syrup (Trial 4) or decreasing syrup addition or centrifuge times (Trial 5 and Trial 7, respectively) increased color in both methods. Decreasing Brix of syrup (Trials 2 and 3) decreased color in Method 4 (Modified) but not in Method 2. Finally, increasing syrup addition time (Trial 6) or centrifuge time (Trial 8) had little effect.



Table 2. Effects of variations in procedure on ICUMSA Method 2 and Savannah Method 4 (Modified) color results for typical Florida raw sugar.

Trial	Brix of affination syrup	Syrup addition time	Centrifug- ation time	Affined color	
				Method 2	Method 4 (Modified)
1	64.2	4.5	2.0	161	885
2	62.1	4.5	2.0	162	864
3	62.1	4.5	2.0	162	865
4	65.9	4.5	2.0	176	921
5	64.2	4.0	2.0	188	883
6	64.2	5.0	2.0	170	902
7	64.2	4.5	1.5	177	919
8	64.2	4.5	2.5	169	896

A comparative study employing 149 Florida sugars from several mills and several crop years illustrates some interesting points. All sugars were analyzed for color by both Method 2 (560nm, pH 7.0) and Method 4 (Modified) (420nm, pH 8.5). The range of colors encountered (Table 3) was fairly broad with Method 2 values from 47 to 293, Method 4 (Modified) whole raw values from 1932 to 12322, and Method 4 (Modified) affined values from 776 to 1870. A conventional correlation analysis was conducted on data from all sugars to compare color ratings according to the Method 2 procedure and the two Method 4 procedures. First, it was found (Table 4) that highly significant correlations (observed significance level less than 0.01) existed among the three types of color results (i.e., Method 2, Method 4 (Modified) whole raw, and Method 4 (Modified) affined). Not surprisingly, the best correlation ( $r^2 = .81$ ) was found between Method 2 and Method 4 (Modified) affined colors. Correlations between Method 4 (Modified) whole raw colors and Method 4 (Modified) affined colors showed that the Method 4 (Modified) whole raw color was a poorer indicator of the corresponding affined sugar color ( $r^2 = .56$ ). This indicates that the darkening of the molasses layer on the outside of the crystal has little to do with the occluded color not washed away in the affination process. Finally, the correlation between Method 2 color and Method 4 (modified) whole raw color was .71.

Table 3. Color results for 149 Florida raw sugars analyzed by ICUMSA Method 2 and Savannah Method 4 (Modified).

Sample No.	Color		
	ICUMSA Method 2	Method 4 (Modified)	
		Whole raw	Affined
1	104	2769	1188
2	107	3389	1208
3	250	6365	1534
4	203	4027	1662
5	174	7140	1679
6	138	5480	1428
7	105	2573	1136
8	117	5089	1120
9	71	2392	1108
10	120	2990	1620
11	123	3066	1606
12	104	2784	1491
13	112	2729	1334
14	110	2657	1267
15	106	2522	1230
16	107	2368	1123
17	100	2260	1111
18	98	2322	1095
19	103	2472	1103
20	100	2631	1107
21	98	2400	1210

(Continued)

Table 3, Cont'd

Sample No.	ICUMSA Method 2	Color	
		Method 4 (Modified)	
		Whole raw	Affined
22	120	2990	1620
23	123	3066	1606
24	172	3517	1684
25	106	3597	1304
26	111	4241	1356
27	105	3601	1244
28	117	3747	1301
29	104	3840	1213
30	113	3650	1236
31	102	2464	1186
32	101	2406	1135
33	115	2977	1218
34	86	2432	1083
35	91	3949	1191
36	137	4593	1336
37	92	3491	1253
38	90	3774	1221
39	93	3799	1195
40	93	3643	1258
41	83	3296	1182
42	88	3184	1200
43	154	2518	1211
44	124	2518	1148
45	88	2167	1038
46	93	2211	1068
47	70	2214	937
48	65	1889	883
49	93	2113	951
50	118	2012	1104
51	99	2084	951
52	78	2703	1135
53	78	2619	1153
54	84	2902	1153
55	64	2507	960
56	79	2482	1047
57	83	2659	1075
58	94	2482	1087
59	75	2431	1052
60	76	2373	1062
61	87	2724	1145
62	77	2674	1150
63	98	2619	1286
64	147	2453	1102
65	117	2565	1111
66	82	2106	945
67	63	1946	822
68	63	2113	841
69	60	1887	797
70	62	2503	925
71	78	2256	1098
72	90	2988	1210
73	70	2438	1054
74	64	2192	971
75	59	2174	966
76	57	2127	909
77	60	2149	925
78	53	2315	937
79	68	2486	974
80	64	2334	1111
81	64	2174	1070
82	61	1932	1042
83	56	2030	940
84	69	2373	1125

(Continued)

Table 3, Cont'd

Sample No.	ICUMSA Method 2	Color	
		Method 4 (Modified)	
		Whole raw	Affined
85	127	2967	1513
86	45	3980	830
87	63	6028	924
88	57	4501	989
89	64	2294	963
90	64	2178	990
91	47	2211	783
92	107	5955	1138
93	55	2247	872
94	76	2355	1099
95	59	2880	1042
96	63	2171	917
97	48	2268	1122
98	62	2312	891
99	60	2793	1046
100	60	2587	942
101	67	2196	1063
102	59	2746	1038
103	232	10390	1627
104	93	3745	1054
105	88	3075	953
106	115	5470	1091
107	74	2500	924
108	101	5412	1021
109	98	2677	1033
110	75	2373	979
111	92	5087	925
112	65	2880	950
113	63	2348	903
114	55	2486	891
115	71	2178	953
116	66	1950	917
117	55	2518	919
118	61	2402	992
119	69	2200	1033
120	50	1896	776
121	63	2633	893
122	293	12322	1870
123	106	3614	1166
124	94	4747	987
125	65	2663	891
126	63	1932	777
127	55	1755	753
128	76	2533	895
129	63	2254	831
130	112	3506	1174
131	99	3458	1250
132	92	3312	1163
133	138	5623	1456
134	82	3610	1072
135	90	4768	1083
136	91	4440	1160
137	118	5614	1323
138	72	3186	1026
139	74	3544	1038
140	80	4279	1156
141	96	3138	1070
142	132	5627	1370
143	120	5878	1444
144	132	4569	1108
145	78	4450	1000
146	93	4334	1166
147	102	4896	1104
148	98	4704	1198
149	108	4780	1032

Table 4. Color premiums and penalties for very good, average, and very poor Florida sugars - Contract #12 vs. Contract #14.<sup>1/</sup>

Sugar	Contract #12		Contract #14		
	Color	Premium (penalty)	Raw color	Affined color	Premium (penalty)
1	47	\$2.59/T	2211	783	\$0.17/T
2	48	2.55/T	2268	1122	0.11/T
3	56	2.26/T	2030	940	0.14/T
4	60	2.12/T	1887	797	0.17/T
5	89	1.08/T	2424	1075	0.08/T
6	74	1.62/T	2296	1092	0.10/T
7	232	(1.32)/T	10390	1627	(3.36)/T
8	293	(8.64)/T	12232	1870	(0.92)/T
9	250	(2.70)/T	6365	1534	(0.27)/T
10	203	---	4027	1662	(0.87)/T

<sup>1/</sup> Contract #12 specified Method 2 color and Contract #14 specifies Method 4 (Modified) color. Statistical correlation ( $r^2$ ) was .81 between Method 2 and Method 4 (Modified) refined colors, .71 between Method 2 and Method 4 (Modified) whole raw colors, and .56 between Method 4 (Modified) whole raw and Method 4 (Modified) refined colors.

An examination of the economic consequences of the redefined color premium-penalty schedule included in Contract #14 of the New York Coffee, Sugar, and Cocoa Exchange is also enlightening (Table 4). While the vast majority of sugars examined over the course of this study would earn sizeable color premiums under Contract #12 terms (i.e., Method 2 color), the newly adopted Contract #14 color procedures essentially eliminate all premiums except some token premiums for whole raw color. The very worst (i.e., highest color) sugars, on the other hand, often are worth more than under the older system.

#### CONCLUSIONS

It appears that Method 4 (Modified) does not measure some new aspect of sugar color more representative of refinery processing conditions but rather provides basically the same information supplied by Method 2 color, at least with Florida sugars. It would be interesting to enlarge this study to include sugars from other origins, as a different mix of colorants might very well produce a different dependence on wavelength and pH. Work by others (2) indicates that the relative proportions of pH-sensitive and pH-insensitive colorants vary somewhat from sugar to sugar.

It would thus appear that the new raw sugar color methodology is based more on economic considerations than on technical ones. It appears to be a step backward in this area of research and does not take into account a great deal of knowledge accumulated in recent years regarding the nature of sugar colorants, how they behave in refining, and how to objectively assess the "refining quality" of a raw sugar. The battery of simple tests suggested by Clarke and co-workers (2) based on the work of Smith and Gregory (9) is an alternative that does relate to "refining quality." In this treatment, the different classes of colorants, their relative ease of removal, and the different requirements of the various refining processes all are brought together in an objective way. A treatment of this type would be an immense improvement over the relatively subjective procedures now used, provided the results of individual component tests could be adequately quantitated.



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USE OF A DEXTRANASE PRODUCED BY LIPOMYCES STARKEYI  
IN A RAW SUGAR MILL

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ABSTRACT

Dextranase derived from the yeast Lipomyces starkeyi was used in a pilot scale test to determine its efficiency in removing dextran from stale cane. A 76% reduction of dextran was measured between treated and untreated sugar. Lipomyces dextranase had optimal activity in fresh cane juice (pH 5.6) between 30 and 40°C. A dose calibration curve was constructed from laboratory studies and compared to the pilot test. The pilot test showed that the enzyme was two fold more efficient in dextran removal than was indicated by laboratory trials.

INTRODUCTION

When dextran is formed in cane juice, it can thicken the juice and make it difficult to process. Some of the dextran is included in final sugar crystals, affecting both their shape and marketability. Sugar refiners, who are the customers for raw cane sugar, now extract a price penalty on raw sugar containing excessive dextran.

Warm, wet weather during the cane harvest season encourages dextran formation. The 1986 Louisiana season had several such spells, resulting in penalties of as high as \$100,000 on a single barge shipment. This economic loss is shared by the farmers and the mill owners. Thus there is strong economic incentive for dextran control in the sugar industry.

Dextranase is a biologically produced enzyme which selectively decomposes dextran into small carbohydrate molecules. Dextranase offers the possibility of practical control of dextran in sugar manufacturing. Application of dextranase in the sugar industry has already been demonstrated overseas (5). Also, the Japanese have shown (1, 12) that inclusion of dextranase in toothpaste can eliminate or greatly reduce dental plaque.

Since both sugar industry and toothpaste applications for dextranase have been demonstrated abroad, why not in the U.S.? The principle reason is the lack of Food and Drug Administration (FDA) approval for current commercial enzyme preparations. Industrial sources of dextranase are species of Penicillium (Novo; DN L25) (9) and Chaetomium (Miles; DEXTRANEX) (8). These fungi can produce various antibiotics and toxic metabolites, hence the lack of FDA approval.

Lipomyces starkeyi, an ascosporogenous yeast, also produces dextranase (3, 6, 13). This yeast is not known to produce antibiotics or toxic metabolites (6). Also, this yeast has been used in food related applications (4). These characteristics increase the potential for FDA approval for dextranase produced by this organism. The purpose of this study was to further characterize and demonstrate the effectiveness of this dextranase in a pilot mill trial at Audubon Sugar Institute.

METHODS AND MATERIALS

Enzyme preparation and assay

Dextranase was produced in a 500 l fermentor as described previously (3, 6). Enzyme was processed by first removing the yeast cells from the fermentation broth, then concentrating the broth to a final activity of 270 IU/ml. One unit (IU) of dextranase is defined as the amount of enzyme which liberates one  $\mu$ mole of glucose equivalents in one minute under the conditions described below. Dextranase was assayed by a modification of the method of Webb and Spencer-Martins (13). Enzyme was incubated with 2.0% (w/v) Dextran T-2000 (Pharmacia) in 0.05 M Citrate-Phosphate pH 5.5 at 50°C for the 10-30 minutes. Activity was determined from the rate of increase in reducing sugars as measured by 3,5-dinitrosalicylic acid method (11).

### Laboratory tests

Fresh mixed juice was spiked with dextran (Sigma Chemical; 40,000,000 mol. wt.) such that the final concentration of dextran was at least 25,000 ppm/Brix (Brix (Bx) = % solids). Dextranase, 0.7 IU/ml, was added to each test. The pH of the final mixture was 5.6 and the incubation temperature was 27°C. Samples were taken at 15-minute intervals for one hour. The reaction was stopped by alcohol precipitation. Dextran was measured by the enzymatic ASI-II method (10).

### Pilot trial

Two slings of sugarcane (2.9 metric tons) were obtained from the LSU Agricultural Research Station at St. Gabriel, Louisiana. From this cane, 2000 l of mixed juice was produced. Sufficient dextran (Sigma Chemical; 40,000,000 mol. wt.) was added to this juice to make it approximately 10,000 ppm/Brix. Dextranase was added to one-half of this juice such that the final enzyme concentration equaled 0.27 IU/ml. The dextranase treated juice was allowed to stand for one hour at 27°C, pH 5.6, before clarification. Both the dextranase treated and untreated juices were processed using standard procedures to produce an "A" strike sugar. Dextran analysis was by the ASI-II method (10) and on sugar by the Haze method (2).

### Dextran analysis

Dextran was measured in cane juice, syrup and sugar by the ASI-II method (10). Briefly, the samples were treated with ethyl alcohol (ETOH) to precipitate all polysaccharides present. The dextran in the reconstituted precipitate, was hydrolyzed with the use of dextranase. A standard curve was used to convert the amount of reducing sugars produced to the amount of dextran present.

Dextran in sugar was also measured by the Haze method (2). This is the method that is employed by the sugar industry. Briefly, the samples are treated with ETOH and a turbidimetric measurement of the resulting precipitate is used to quantify dextran content.

## RESULTS AND DISCUSSION

The optimum temperature for Lipomyces dextranase activity in cane juice was between 30 and 40°C (Table 1), although there was a significant amount of dextran removed (74%) at 50°C. The temperature optimum in juice was 10°C lower than reported values for both the Miles DEXTRANEX (8) and the Novo DN 25 L (9). Lipomyces dextranase does exhibit a temperature activity optimum of 50-60°C when assayed for dextran removal in a defined reaction mixture (13). Some component in cane juice appears to be having an adverse effect on the activity of this dextranase. There have been reports of enzyme inhibitors contained in mixed juice (7). These inhibitors may contribute to the shift in temperature optimum observed with the Lipomyces dextranase.

Table 1. Removal of dextran from mixed juice: effect of incubation temperature. 1/

Incubation temperature (°C)	Incubation period (min)	Dextranase concentration (IU/ml)	Dextran concentration	
			Start (ppm/Bx)	Final (ppm/Bx)
20	40	5.4	28263	6760
30	40	5.4	28263	1025
40	40	5.4	28263	1030
50	40	5.4	28263	7440

1/ Dextran analysis by the ASI-II method. Values are averages of triplicates.

The shift in temperature optimum is not related to differences in enzyme since the same enzyme was used in all tests. Substrate differences, if any, do not play a major role in the determination of the temperature optimum, due to the relative nature of these comparisons.

The lowered temperature optimum found with *Lipomyces* dextranase will not be a problem for treating cane juice prior to clarification, since the temperature of the juice is rarely above 40°C. But it could be a problem for the treatment in syrup, where the temperatures are usually above 70°C. DEXTRANEX (Miles) has been recommended for use in syrups (9). The Australians recommend dextranase treatment just prior to clarification (5), utilizing large mixed juice tanks for reaction vessels.

Figure 1 shows a typical enzyme response curve, with the rate of dextran removal decreasing in cane juice as the dextranase concentration decreases. As expected, the enzyme worked at a constant rate (Figure 2). This means that the degree of dextran removal will be time and enzyme concentration dependent. From this data it was possible to construct an enzyme dose rate to fit a specific situation. If pure enzyme is used (1400 IU/mg protein), the dose required to completely remove 1000 ppm/Brix dextran in mixed juice (15 Brix, 27°C holding temperature for 20 minutes) is 2 ppm. This value is calculated on purified dextranase and will be higher for crude enzyme preparations.

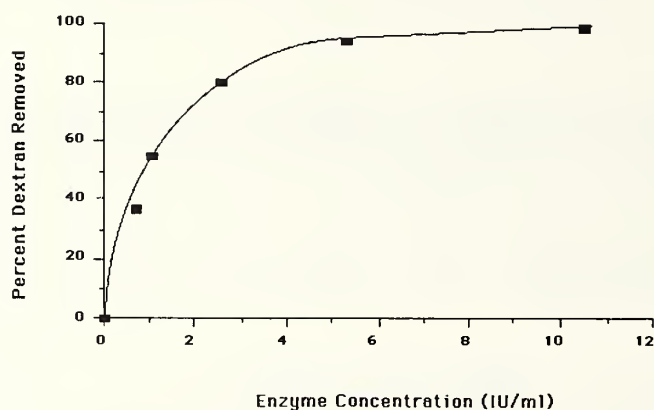


Figure 1. Effect of enzyme concentration upon dextran removal from cane juice (40-minute incubation at pH 5.4, 25°C). Dextran analysis by ASI-II method. Values averages of triplicates.

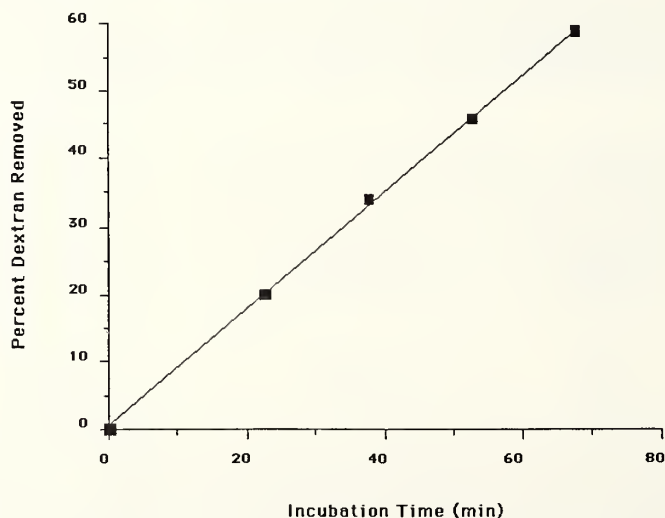


Figure 2. A time course of dextran removal from cane juice (0.7 IU/ml, pH 5.4, 25°C). Dextran analysis by ASI-II method. Values averages of triplicates.



An adequate supply of naturally contaminated cane was not available during the 1987 season for a pilot test, so fresh mixed juice was spiked with dextran. Dextran additions were made to a level higher than what normally might be encountered in a commercial situation. The enzyme dose was lower than would be recommended under normal applications. All pilot tests were performed at ambient temperature (27°C) due to the inability for temperature control of the treatment tank.

In the pilot trial, the clarified juice showed a 45% decrease in dextran after exposure to dextranase for an hour (Table 2). Extrapolating from the calibration curve (Figure 2) a 22% reduction in dextran was expected in the mill trial. Approximately twice as much dextran was removed than was expected. This observation could be due to differences in lots of cane juice, since the laboratory and pilot trial juices were prepared separately. Furthermore the mud content was very high in the laboratory cane juice as compared to juice from the cane used in the pilot trial. It might be construed therefore that our dosing estimations are conservative. Although it is more likely that the laboratory results more closely parallel a "realworld" situation found with stale cane. Further pilot trials utilizing naturally contaminated cane will be required to confirm this.

Table 2. Removal of dextran: pilot mill trial. 1/,2/,3/

Sugar product	Dextran concentration			
	Untreated (ppm/Bx)	( $\pm$ SD)	Treated (ppm/Bx)	( $\pm$ SD)
Clarified mixed juice (ASI-II)	10870	342	6028	365
Syrup (ASI-II)	10540	140	5714	512
Sugar (ASI-II)	3625	95	1155	74
(Haze)	2240	--	540	--

1/ Dextran analysis method as noted in table.

2/ Values are averages of triplicates, except for the Haze test.

3/ Test parameters: 0.27 IU/ml enzyme; 27°C; pH 5.6.

The untreated juice was impossible to boil and could not be adequately purged. The small amount of sugar that could be recovered was dark in color and the crystal was elongated (needle grain) (Figure 3B). The dextranase treated material boiled normally and the sugar produced did not exhibit the degree of crystal elongation observed with the untreated sugar (Figure 3A).

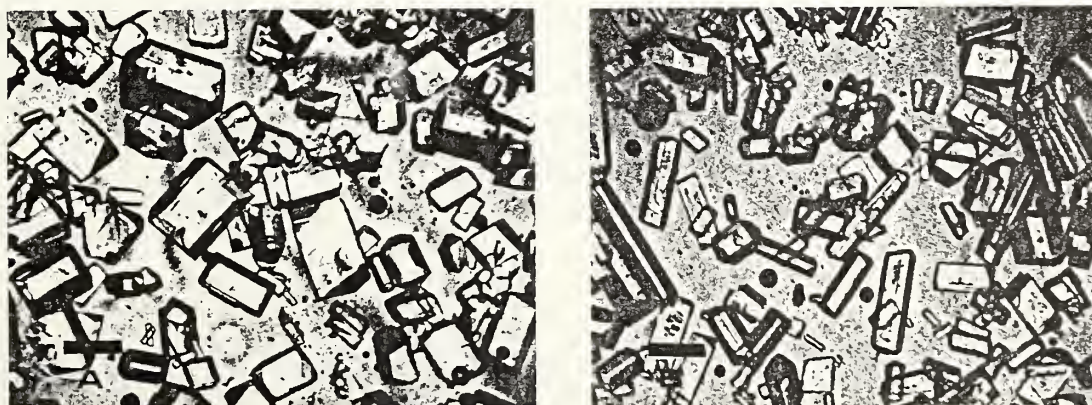


Figure 3. A comparison of treated (A) versus untreated (B) "A" strike sugar. Scale = 30  $\mu$ m.

Dextran analysis of the syrup and the sugar produced demonstrated the effectiveness of the enzyme in removing dextran from cane juice. A 76% reduction in dextran content, by Haze, was seen between the treated and untreated sugars. By increasing the dextranase dose or holding time it should be possible to make sugar with a dextran content below the penalty level using Lipomyces dextranase. A full scale mill trial is planned for the application of Lipomyces dextranase during the 1988 sugar season.

#### ACKNOWLEDGMENTS

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## MUD FILTRATION ALTERNATIVES<sup>1/</sup>

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### ABSTRACT

Sugar losses in filter cake in Louisiana remain much higher than desirable. At least two pounds of additional sugar per ton of cane should be easily recovered if filter operation is improved. Results are presented for a survey of mill filter operations, for laboratory test work on filter cake characteristics and for several approaches to double filtration systems.

### INTRODUCTION

Rotary vacuum filters are standard equipment in the raw sugar factory and are well suited to the dual application of both dewatering and washing the clarifier mud. They appear to be the most suitable equipment for this role and their performance and operation have been much studied. In Louisiana the mud filter is often a neglected and underestimated source of sugar loss. Data for the 1983-1986 seasons are given in Table 1. These data are taken from the individual factory reports that are collated and circulated (3). These reported numbers are often suspect due to sample handling and analytical and reporting procedures. Reducing the sucrose in filter cake to an acceptable level could mean, for the average factory, production of additional sugar worth about \$100,000 for the crop.

Table 1. Louisiana filter losses and recoverable sugar.<sup>1/</sup>

Year	Pol % filter cake	Lb filter cake per ton cane	Lb sugar recovered per ton cane	\$ per day
1983	4.4	78	1.40	1,400
1984	4.3	82	1.42	1,420
1985	4.1	103	1.62	1,620
1986	4.0	96	1.44	1,440

<sup>1/</sup> At pol % filter cake = 2.0.

This report is intended to show how significant these losses are, how they may be minimized and to describe some test work involving new types of filter and alternative mud handling processes. Several alternative approaches have been described previously, including pressure filtration (4), horizontal vacuum filters (5), centrifugal dewatering (12) and solid bowl centrifugation (13). The systems described in this paper may be considered as complementary to conventional vacuum filtration. In Louisiana the bulk of the losses may be attributed to poor operation and maintenance, rather than limitations of the equipment. Recent work in Australia has shown that sugar losses may be significantly reduced by modifications in the design of the filter (7,8).

<sup>1/</sup> Approved for publication by the Director of the Louisiana Agricultural Experiment Station as manuscript #88-61-2154.



## MATERIALS, METHODS AND EQUIPMENT

1. Flocculants used in this study were gifts of the manufacturers or their agents.
2. Routine purity determinations involved measurement of refractometric Brix and polarization after clarification with lead subacetate.
3. The quantities of insoluble material in mixed juice, clarifier feed, clarifier mud and filtrate were estimated by centrifugation at 500 g for 10 minutes. The settled mud volume (%) was converted to the dry weight by multiplication by a factor of 0.32 (the correlation coefficient between volume and weight of solid was 0.83).
4. The Brix of the residual juice in discharged filter cake was determined by squeezing a sample, after mixing, in a cloth onto the refractometer.  
  

$$\text{[If moisture in filter cake} = m\%, \text{ Brix of residual juice in cake} = b \text{ and filtrate purity} = f; \text{ then pol \% filter cake} = m \times b \times f / 100 / (100-b)\text{].}$$
5. Standard factory practice for pol in filter cake involves dilution of 25g of filter cake to 100 ml, mixing and clarification with dry lead subacetate. An improved procedure involves using 333 g of filter cake and blending at low speed with 1000 ml of water, followed by clarification with dry lead subacetate. Advantages are the use of larger samples and ease of preparation.
6. The percentage fibre (bagacillo) in filter cake was determined by drying two equal samples, one as taken from the filter and the other after extensive washing on a 100 mesh filter.
7. Filter cake calorific values were determined using a Parr adiabatic bomb calorimeter.
8. Spray nozzles were purchased from Bete Fog Nozzle Inc. (Equivalent nozzles were available from other suppliers.)
9. The pilot scale membrane press was supplied by the Putsch Company and operated by their staff at the Breaux Bridge Sugar Cooperative.
10. The belt press was supplied by Silver Engineering and operated at Raceland Factory. The equipment was truck mounted and was equipped with gravity drainage and low and high pressure sections. The belt width was 48" giving a cake width of 42".
11. A small rotating screen device (Figure 1) was constructed at ASI to drain excess juice from thin clarifier mud. The length was 30" and diameter 8"; the slope was about 15; 30 mesh screen was found to be optimum.

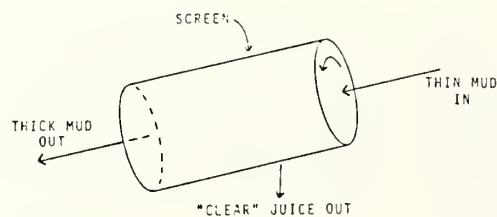


Figure 1. Rotating dewatering drum.

12. For the 1986 crop a vacuum belt filter was modified to act as a mud thickener with drainage of excess juice by gravity (Figure 2). The drainage section was 24" wide and 120" long. The belt speed could be varied up to 25 ft/min. The screen used was 30 mesh polypropylene.



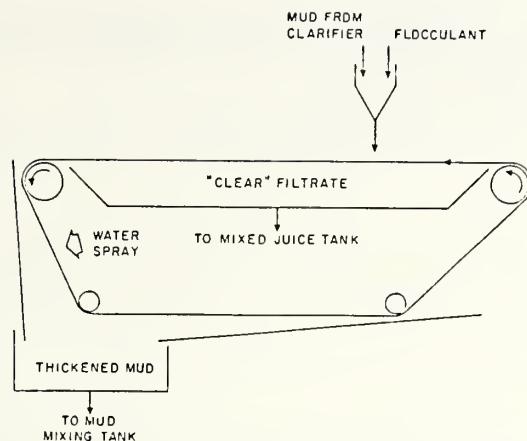


Figure 2. Dewatering belt filter.

## RESULTS AND DISCUSSION

### Survey of filter operation

The data shown in Table 1 are based on mill reported data and underestimate the magnitude of the problem of poor filter operation. Mill filter cake analytical data were poor and frequently much lower than indicated by measurement of the residual juice Brix by direct measurement by Audubon Sugar Institute (ASI) personnel. Typical data were mill reported data for the day of 3.6; spot samples over the day by ASI of 6.1, 7.2, 6.4, 5.4, 7.3, 6.4 and 8.9 (for the last three, the expected values based on residual juice Brix, were 7.4, 6.4 and 8.6). The data for measured and calculated mud pol values are shown in Figure 3. Calculated values were sometimes higher than measured but not lower; this is presumably due to drying out of the sample. The Brix of the residual juice in cake, expressed as a percentage of clarified juice Brix, averaged 69%, with a high of 100 and low of 55.

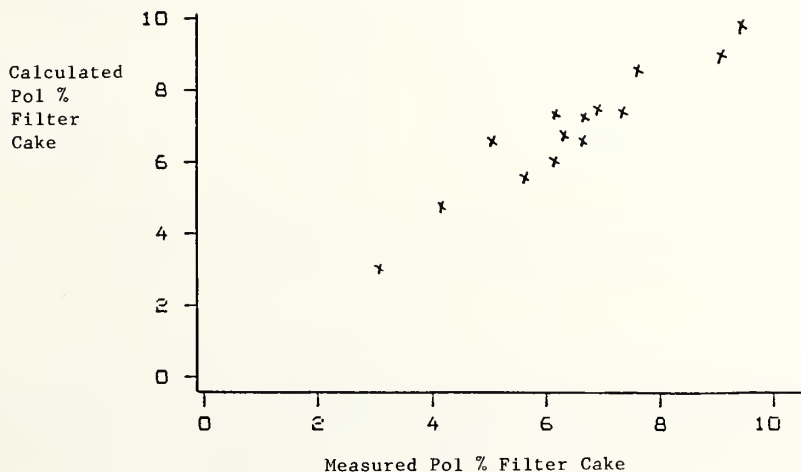


Figure 3. Relationship between directly determined pol % filter cake and the value calculated from the Brix of the residual juice in the cake.

A survey was carried out to determine typical operating conditions and results for the Louisiana sugar mills. Each mill was visited several times, and while this cannot give a true picture of the operation of any one mill, the results show the range of problems in the industry.

The installed filter capacity (sq. ft. per ton cane per hour) averaged 4.7 with a high of 9.3 and low of 2.4. Actually operating data averaged 3.4 with a high of 5.9 and low of 1.4.

Rotational speed (rph) averaged 25 with a high of 42 and low of 12. The area swept (sq. ft. per ton of cane) averaged 85 with a high of 171 and low of 43.

The vacuum applied to the filters varied considerably and eight mills had vacuum gauges that were non-functional. Only five mills had satisfactory vacuum applied to the filter; the pick-up vacuum (in. Hg) averaged 11 with a high of 20 and low of 3; the wash/dry vacuum averaged 15, with a high of 22 and low of 5.

Flocculants were used in clarifiers and filters at most mills six different flocculants were noted. Lime addition to mud was common practice at about half the mills. The pH of filter feed varied from 6.3 to 8.6 with a mean of 6.9. The temperature of feed to the filter averaged 77°C with a high of 90°C and low of 67°C.

Neither the volume of water applied to the filters nor the quantity of bagacillo added at the mud tank could be quantified. Only five mills were judged to be applying plenty of water and two were not using any water. Only six mills were judged to be using a reasonable quantity of bagacillo and two were not using any. Equipment for producing and/or conveying bagacillo was inadequate in several cases. Methods for bagacillo collection and handling have been reviewed by Badley (2). The fibre content of the cake is determined by that passing through the clarifier and the bagacillo added at the mud mixing tank. Values measured varied from 10 to 34% in 1984 and 22%, 26% and 21% on average for repeated tests at three mills in 1987. These low levels reflect the amount of fibre in the mud passing through the clarifier.

Cake thickness and solids retention were generally satisfactory with the retention on the cloth filters being virtually 100%. Settled solids content (volume % as determined by centrifugation) are given in Table 2. About 10% water was added to the clarifier mud before it was fed to the filter.

Table 2. Solids content of process streams.

Stream	Solids content by centrifugation (%v/v)		
	Mean	High	Low
Mixed juice	6	9	3
Clarifier mud	55	79	35
Filter feed	49	70	19
Filtrate (screen filters only)	10	38	2

Filtrate purity measurements are not routine, but measurements made by ASI indicate that the purity drop between clarified juice and filtrate is about 3 points. Temperatures measured in the boot of the filters were usually in the range 70-75°C.

Most mills operate their filters on a continuous basis. However, a few operated intermittently. The mud level in the clarifier was allowed to rise to a maximum level and then lowered by fairly rapid filter operation until the mud being discharged from the clarifier was too thin for filter operation, when the filter was shut down. In at least one mill the filter ran flat out about 12 hours per day. Wide fluctuations in filtrate pH were observed as a consequence of continuous addition of lime to the mud mixing tank when the mud discharge from the clarifier was intermittent.

#### Laboratory experiments

Although the quality of clarified juice may be satisfactory, the mud from the clarifier may not be suitable for efficient filtration. Further flocculation of

the mud is usually necessary as part of the conditioning process to produce a porous cake. Liming of the mud assists in the flocculation, but the production of really well flocculated mud usually required the addition of polymeric flocculants. These flocculants increase the retention of fine particulate matter and so help produce a better filtrate. Experiments to determine the optimum dosage of flocculant and typical results are shown in Figure 4. The optimum level for addition of flocculant to filter feed appears to be about 15 ppm, similar to that published (9).

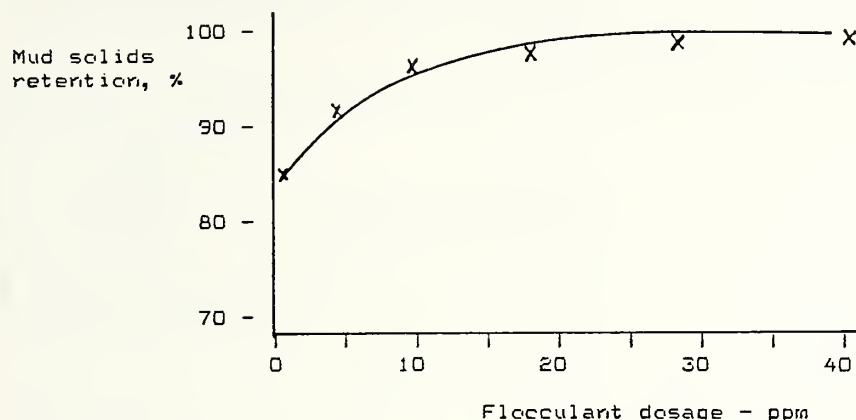


Figure 4. Relationship between mud solids retention and dosage of flocculant. Feed 43% solids by centrifugation; 2.5% bagacillo (dry basis) added to the feed. Wash water flow through the cake of 0.40 cake volumes per minute.

Both the cake thickness and the cake porosity depend primarily upon the percentage of bagacillo in the feed. Too high a solids level in mud results in an impermeable cake and too high a level of fibre results in problems of holding vacuum. In laboratory tests, vacuum was only held by mud from the clarifier, before addition of bagacillo, with a solids content (by centrifugation) above 30% and was best at about 35%. At higher values, the percolation rates decreased significantly (Figure 5).

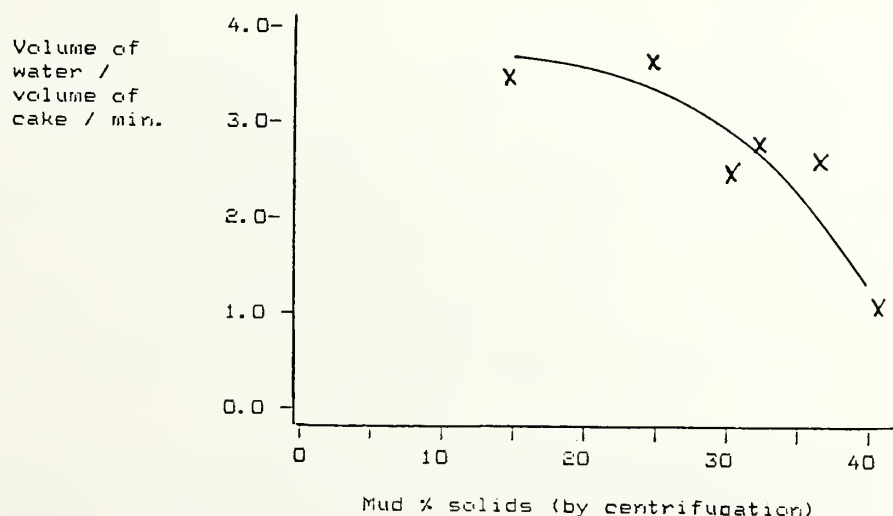


Figure 5. Relationship between mud solids and percolation rates of wash water, expressed as volumes of cake per minute. 2% bagacillo (dry basis) added to feed 15 ppm flocculant added to feed.

### Spray nozzles

The nozzles tested are designed to avoid choking with fine particulate matter, e.g., bagacillo. This proved to be the case with fine bagacillo, but all the nozzles tested became blocked when presented with larger bagasse particles. In-line strainers with 20 mesh screen are necessary to catch material large enough to block the nozzles.

Six different nozzles were tested, and at least two are judged to be suitable for use on the filters. Results are given in Table 3. Of those listed, TF6FCN and WT50115 were probably the best, but TF6FC and TF6NN were both acceptable, with TF6FC perhaps giving too wide a spray causing water to miss the filter.

Table 3. Performance of spray nozzles.

Cat. #	Comments	Flow (gpm) at		Free passage diameter (in.)	Width covered 1 ft. from surface
		35-40 psi	45-50 psi		
TF6N	Spray too coarse	-	-	-	-
TF6FC	Wide spray (120)	1.3	1.6	3/32	24"
TF6FCN	Good fine droplets but rather hard at higher pressure	1.3	1.7	3/32	18"
TF6NN	Fine droplets but rather hard at higher pressure	1.3	1.7	3/32	16"
WT50115	Good spray	0.4	0.5	5/64	16"
WT130130	Spray too coarse	-	-	-	-

### Membrane press

The membrane press is a type of automatic plate and frame filter that allows the cake to be dried by application of air pressure. The purpose of the test was to estimate the feasibility of processing the clarification mud through such a filter as a means of easing the mud disposal problems at Breau Bridge factory. Prior tests had been carried out by the Putsch personnel on filtration of mud direct from the mud tank after addition of bagacillo. Without washing the cake in the press, (difficult in the press as set up), the residual pol loss in the cake, although lower than then achieved by the factory, would not be totally satisfactory.

The runs reported here were all carried out on the slurried filter cake from the Eimco belt filter. This slurry is the material that is usually sent for disposal. Analyses of the slurried filter cake indicate pol levels between 6 and 8%, consistent with the pol % filter cake of 8 to 10%. Juice squeezed from the Eimco filter cake had Brix values between 10 and 12 before slurrying with the disposal water.

The experimental data are given in Table 4. The optimum insoluble solids content of the material sent to the pilot filter was in the range 12 to 15%, and this was achieved by mixing the slurry with water. Flocculant was added in the range 8 to 10 ppm on solids. Initial runs were carried out at approximately 50°C and later, more satisfactorily, at 85° to 90°C. No washing of the cake on the press was attempted, and the reduction of pol in the cake was a result of the low moisture in the cake and the dilution of the slurry to 12 to 15% insoluble solids.



Table 4. Performance of membrane press.

	Test <u>1</u> / at 50°C	Tests <u>1</u> / at 87°C
Slurry composition		
% Moisture	74.4	71.8
% Insoluble solids	17.4	20.8
% Soluble solids	8.1	7.4
% Pol	6.7	6.0
Slurry:water ratio	1.00:0.63	1.00:0.67
Press filtrate composition		
% Brix	4.6	4.2
% Pol	3.8	3.4
Cake composition		
% Moisture	44.5	42.9
% Insoluble solids	49.2	55.3
% Soluble solids	2.4	1.8
% Pol	1.9	1.4
Pol recovery (%)	89.0	90.0

1/ Data averaged for each series of tests.

Under average conditions for mud production, with no washing on the primary filter, slurrying of the cake and treatment of the slurry with the membrane press, the sugar loss per ton of cane would be less than two pounds compared with about five pounds without the press. The improved sugar recovery is due to both the washing by dilution and the lower cake moisture from the press.

The residual material from the belt press, at 40 to 50% moisture and 1 to 2% pol is much more amenable to storage and transportation than the current slurry. These dual advantages, combined with the lower environmental impact of disposal, even considering the fairly high cost of the system, suggest that there are circumstances where it would be applicable.

Another advantage of the much drier press cake may be that it would be of sufficient calorific value for combustion in modern sludge-fueled furnaces. In connection with the evaluation of the Putsch membrane press at Breaux Bridge, the calorific value of dried filter cake was determined for samples from several mills. Most of the samples were from Breaux Bridge, either conventional samples or of cake from the membrane press. Samples of cake and/or slurry were dried to constant weight, and sulphated ash and silica were determined for all samples.

The average calorific value obtained was 4,160 BThU/lb dry basis with a maximum of 6,000 BThU/lb and a minimum of 3,020 BThU/lb. The minimum calorific value given for combustion of sludge is 3,000 BThU/lb (10). There was very good correlation between the calorific value and the sulphated ash, a measure of the total noncombustible material in the sample (corr. coeff. 0.97). Poor correlations were obtained between the silica and the sulphated ash and between the silica and the calorific value. No difference was evident between regular rotary filter cake and that from the membrane press. The wide range of calorific values obtained was presumably due to variation in the fibre content of the filter cake.

#### Belt press

Data on the successful use of the belt press for cane mud handling in Florida have been published (11). For the tests in Louisiana, the belt press was set up to handle either clarifier mud directly or the mud from the Eimco belt filter which had been slurried for discharge. The mud suspension from the factory process stream was pumped to the press and treated with flocculant in an in-line mixer. After

a few trials, the flocculant (Separan AP30) concentration was set at 0.5% with a delivery rate of about 30 gph to give a final flocculant concentration in the range 5 to 10 ppm. The flocculant addition rate was varied to maximize drainage on the gravity section so that a stable cake passed into the sandwich section of the press to avoid extrusion through the sides of the belts.

The slurry feed rate was increased to maximize the thickness of the cake, and therefore the throughput, again limited by the need to get sufficient drainage in the gravity section to obtain a solid cake passing into the sandwich section. The squeeze on the cake was increased to the point where the dry cake was being extruded through the pores in the fabric, making it difficult to clean with the showers in the system. The wash water from the showers was diverted so that it was not mixed with the filtrate. No attempt was made to change the temperature of the material, it being determined by that of the feed and the natural cooling of the system. Once steady operation of the system was achieved, samples of feed, filtrate and residual cake were taken and analyzed for pol, soluble solids and, where appropriate, moisture and insoluble solids content. Most of the tests were carried out using the cake from the Eimco belt filters reslurried in the water used to wash the cloths. This arrangement made it difficult to vary the solids content of the slurry feed to the belt press. The results for the tests are given in Table 5. It should be noted that, with the reslurried cake, the analytical data are close to the lower limits of sensitivity of the methods used and there is rather more error in measurement than desirable.

Table 5. Performance of belt press.

	Tests <sup>1/</sup> using clarifier mud as feed	Tests <sup>1/</sup> using slurried Eimco cake as feed
Settled solids % feed	17.8	21.8
Cake % moisture	-	66.8
Cake % pol	4.9	0.4
Filtrate data		
Filtrate from thickener		
Settled solids % filtrate	3.7	2.8
Filtrate Brix	8.7	1.2
Solids retention %	84.0	90.0
Filtrate from gravity section		
Settled solids % filtrate	-	2.3
Filtrate Brix	-	1.2
Solids retention %	-	74.0
Combined filtrate		
Settled solids % filtrate	1.3	1.7
Filtrate Brix	8.7	1.0
Solids retention %	93.0	91.0

<sup>1/</sup> Data averaged for each series of tests.

The pol % Eimco filter cake varied between 2.7 and 3.8 and, taken with the data from the table, gives an average pol recovery of 85%. The belt press cake % pol with clarifier mud as feed is higher than that from the Eimco filter since it is not possible to wash on the belt press. The retention data compare very favorably with data for the operation of the rotary vacuum filters in Louisiana.

Filtrate temperatures were in the range 65 to 75° C, rather high for use as imbibition on the mill. The pH of the filtrate ranged from 6.6 to 7.0. The slurry feed rate averaged about 300 lb/min., about one-seventh of the total production rate at Raceland under average conditions. The feed rate was limited by the inadequate flocculation and drainage and/or by the short length of the gravity section.

#### Mud thickening

Initial data on juice recovery and drainage rates were obtained using a 30 mesh, 10-inch diameter sieve. Known volumes of flocculated clarifier mud were poured carefully onto the sieve and the juice flow rates and recoveries determined. Typical results are given in Figure 6; juice drainage was essentially complete in all tests after 3 to 5 minutes.

For the quantities of flocculated mud used the thickness of the drained cake increased linearly with the quantity of mud used (Figure 7). However, with much higher quantities, the thicker settled cake would be expected to impede juice flow. Drained cake thicknesses up to about 25 mm should be practical. Clear juice added to the flocculated mud before drainage was recovered completely, confirming that the drained cake quantity is determined only by the fraction of mud in the applied material.

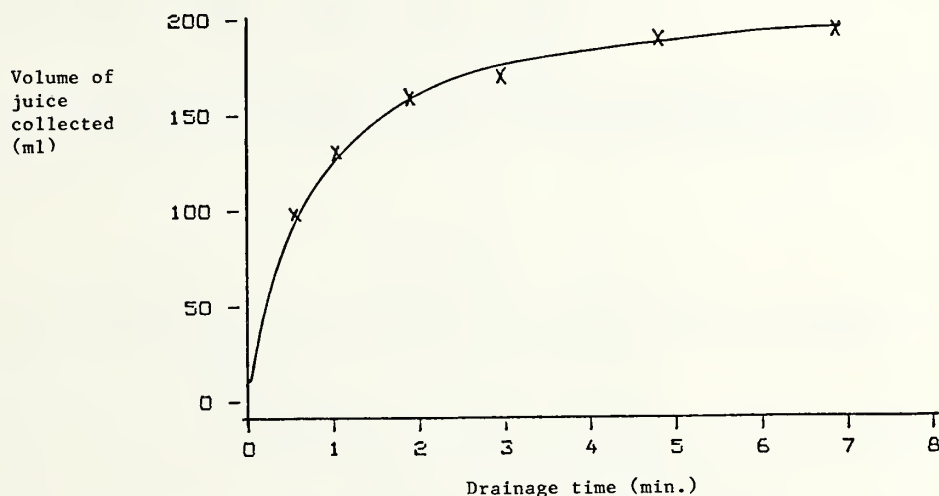


Figure 6. Juice drainage as a function of time. Five hundred ml of flocculated mud on a 10-inch screen.

The first factory tests were carried out on a small rotating screen device constructed to drain excess juice from thin clarifier mud. Its purpose was the recovery of juice for recycle without the use of a conventional filter and to produce a heavy mud of even consistency that could be diluted with the water to give an even feed to the regular filters. Results of the tests are given in Figure 8. The performance of the thickener could be predicted from the solids content of the feed as determined by centrifugation. These results indicate that the sugar loss at the filters could be reduced by about 50%, but these tests gave no capacity data.

For the 1986 season a belt filter was modified to act as a mud thickener with drainage of excess juice by gravity. Good flocculation was essential for the mud solids to be retained by the screen. Typical data are given in Table 6. Using these data to give a drainage time of 30 seconds, with a belt speed of 12 ft./min. and a cake thickness of 0.4", then per foot of width per minute, 0.4 cubic ft., or 30 lb. of thickened mud will be produced. Assuming 100 lb. of mud per ton of cane and 200 tons of cane per hour, this would require such a filter to be about 11 ft. wide with a drainage length of about 6 ft. This may not be too practical. Moving belt drainage systems are in use for fly-ash collection, primary clarification of river water and similar uses (6).

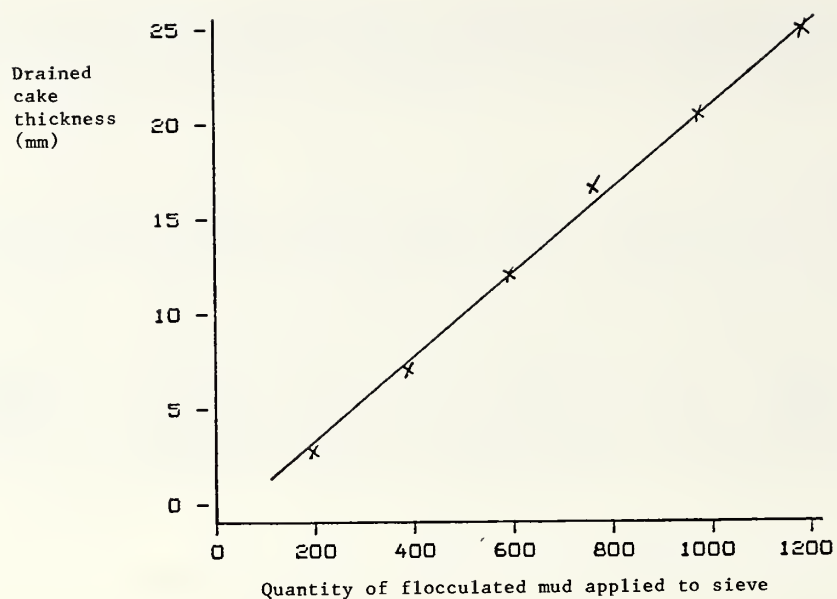


Figure 7. Relationship between drained cake thickness and quantity of flocculated mud applied to sieve.

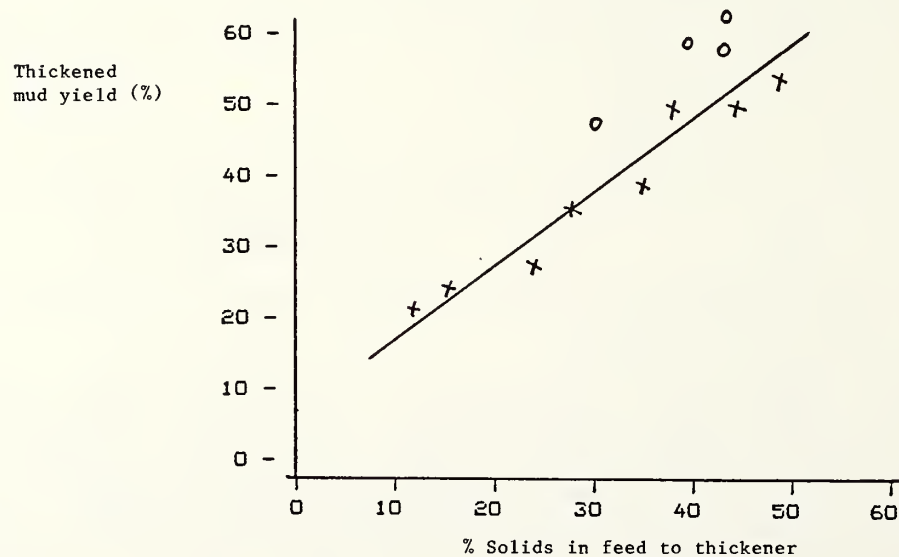


Figure 8. Thickened mud yield (% on feed) vs the solids content of the feed (%v/v).  
 o - feed containing added bagacillo;  
 x - feed without added bagacillo.



Table 6. Performance of belt mud thickener.

	Run 1	Run 2	Run 3
Belt speed (ft/min)	25	18	13
%Insoluble solids in feed to thickener as determined by centrifugation	26	22	22
Weight of juice obtained through the screen as % of thin mud feed	53	58	60
% Insoluble solids in juice passing through the screen	0.3	1.8	1.2
Suspended solids in juice passing through the screen as % of suspended solids in feed	0.4	4.7	3.3
Cake thickness on screen (in.)	0.4	0.4	0.3

As part of these tests it was necessary to compare the performance of commercially available flocculants: - for use at the filter - (Separan AP273P; Talosep A3; Zuclar 2000) > (Separan AP 30; Talosep A5) > (Nalco 7415) - for use in a thickener - (Zuclar 2000) > (Nalco 7415) - Talosep A5; Talosep A3) > (Separan AP273) > (Separan AP30).

#### CONCLUSIONS

Significant benefits to the industry may be achieved by improved filter operation, especially improved mud conditioning and increased cake washing. However, the need for such improvement will not be apparent until good analytical data is routinely available to the mills.

Two pilot scale studies have been made of secondary filtration steps using a membrane press and a belt press. Both gave very good sugar recovery, but there are problems of expense and the recycling of fairly large volumes of very dilute filtrate back into the process. The use of such a second filter stage does not seem to be justified except where the pol in filter cake cannot be reduced in any other way and/or when disposal problems become too severe. Belt presses have been installed in Florida with current operation better than originally published (1).

Under conditions where heavy mud cannot be produced in the clarifier, the removal of excess juice from the mud using a belt thickener has been demonstrated to be feasible. Good flocculation is essential for such a system, and further work is required to obtain good design data for factory scale equipment.

#### ACKNOWLEDGMENT

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## ABSTRACTS - AGRICULTURE

### INTEGRATED MANAGEMENT OF THE SUGARCANE BORER

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To evaluate the relative contributions of varietal resistance, predation, and insecticidal control of sugarcane borer, a split-split plot treatment arrangement was employed with four replications of three commercial varieties of cane; resistant (CP 70-330), moderate (CP 65-357), and susceptible (CP 61-37); and plots with and without predators. Varietal resistance as a sole management tactic across all treatment combinations reduced sugarcane borer damage by 3.6-fold and adult production by 11.6-fold. Predatory pressure caused 1.9- and 3.2-fold reductions; and two properly timed applications of insecticides provided 8.4- and 10.8-fold reductions, respectively. A combination of all three management tactics was found to be additive and reduced damage 57-fold and moth production 330-fold.

### EFFECTS OF GYPSUM ON AN ALLIGATOR CLAY SOIL AND SUGARCANE IN LOUISIANA

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An experiment was conducted to determine the effects of mined gypsum ( $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ ) on soil chemical and physical characteristics and how it affects sugarcane yields and the levels of macro and micronutrients in the plant tissue.

Gypsum was applied to an Alligator clay soil (Vertic Haplaquept, montmorillinitic, acid) at four rates: 1, 2.5, 5, and 10 tons/acre and check plots were included. Cane and sugar yields for plant cane increased for all treatments and approached significance with the 10 tons/acre being significantly different from the control, the 1 ton/acre, and the 2.5 tons/acre treatments.

Extractable  $\text{SO}_4^{2-}\text{S}$  increased significantly with all gypsum treatments in the Ap and AC horizons for the first year and throughout the soil profile for the second year. Since this soil had high levels of exchangeable Ca, during the first year only the highest treatment showed any significant increase in the Ap horizon, for the second year the same results were obtained for this particular horizon, but both the 5 and 10 tons/acre treatments showed significant increases in exchangeable Ca in the AC horizon.

Sulphur present in leaf tissue increased significantly with gypsum applications but was not significantly different between years. Root density in the Ap horizon showed an increase with the higher gypsum rates but was not significant.

### SUGARCANE RESPONSE TO SUBSURFACE DRAINAGE: 20 YEARS OF RESEARCH

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Experiments with small (0.01 acre) replicated field plots and demonstrations in large (up to 10-acre) fields during the past 20 years, showed that subsurface drainage effectively increased sugar yields, particularly during wet (above normal rainfall) years. The first had an annual average of 1,428 lbs./acre more than did plots which had no subsurface drainage. In addition, five crops were harvested from one planting with fifth-crop yields in the drained plots at an acceptable level of 4,465 lbs./acre (CRS).

The next experiment showed that poor drainage (high water table) during the cane's dormant season adversely affected yields. Cane yields in third ratoon were 33 and 15 tons/acre, and sugar yields were 5,860 and 2,960 lbs./acre from low water tables (well drained) and high water tables (poorly drained) treatments, respectively. High and low water table treatments were imposed only during the growing season in plant and first stubble, but continuously during second and third stubble. Significant differences in yields were shown only from second and third stubble crops.

In another experiment, cane and sugar yields declined as duration of wet soil increased. The soil was saturated for 0, 7, 14, and 28 days followed by subsurface drainage for the remainder of a two-month cycle before repeating the treatments twice during each growing season. Cane and sugar yields declined at a rate of 0.4 tons/acre and 63.5 lbs./acre, respectively, for each day the soil was saturated.

Subsurface drainage demonstrations were conducted beginning in 1974, first in Terrebonne Parish on Mhoon silty clay loam soil, then in St. James, St. Mary, Iberia, Iberville, and Assumption Parishes on Commerce silt clay loam, Baldwin silty clay, Jeanerette silty clay loam, Sharkey clay, and Commerce silt loam soils, respectively. Sugar yields from subsurface drained land were usually higher than those from nondrained land, particularly during wet (above average rainfall) years. The highest percent increase in yield of sugar at each field site was: 20 percent in Terrebonne Parish in 1975; 35 percent in St. James Parish in 1985; 22 percent in St. Mary Parish in 1979; 79 percent in Iberia Parish in 1982; 18 percent in Iberville Parish in 1981; and 31 percent in Assumption Parish in 1986.

In addition to increasing yields, subsurface drainage also increased stand longevity. In almost every experiment, yields in the drained areas declined at a slower rate than in the nondrained areas. Furthermore, the effectiveness of subsurface drainage on increasing stand longevity was demonstrated in the field by producing four stubble crops instead of the normal two.

#### FEEDING AND SURVIVAL OF SUGARCANE GRUBS INFECTED WITH MILKY DISEASE

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Third instar larvae of Cyclocephala parallela and Ligyris subtropicus were collected from Florida sugarcane fields from September to April 1985-87. These grubs were tested as healthy grubs which were found not infected with the bacteria, Bacillus popilliae, or as milky grubs which were found infected with the bacteria. Milky grubs in both grub species consumed less carrot and lost more weight in feeding tests than healthy grubs. In survival tests, the median survival of healthy grubs was +30 days in both species. In contrast, the median survival of milky grubs of C. parallela and L. subtropicus was only five days and eight days respectively. Our data show that B. popilliae is a subtle, but important biological control agent since the milky disease reduces grub feeding and also a continuous mortality factor on grub populations from September to April.

#### EFFECTS OF RATOON STUNTING DISEASE ON FOUR COMMERCIAL SUGARCANE CULTIVARS GROWN IN FLORIDA

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Four RSD yield-loss trials, two each on sand and muck soils, were established in late 1985 and harvested in March and April 1987. In each trial, cultivars CP 65-357, CP 70-1133, CP 72-1210, and CP 74-2005 were tested in a randomized-complete-block, split-plot design with eight replications of main plots. Each main plot comprised a healthy and diseased subplot of a cultivar; each subplot was four rows by 17.5 feet. Seedcane for the plots came from an increase nursery at Canal Point. To establish the nursery, seedcane was heat-treated and one-half of the single-node cuttings from this seedcane was then inoculated with the F<sub>1</sub> strain of the RSD bacterium, Clavibacter xyli subsp. xyli.



A significant loss in tons of sugar per acre was detected for each cultivar at one location on sand. At the other locations, similar losses were detected for each cultivar at one location on sand. At the other locations, similar losses were detected for some of the cultivars. In a combined analysis of the data for the four locations, significant losses ( $P < 0.01$ ) were detected for each cultivar. When averaged across all cultivars and locations, the loss was 684 pounds of sugar per acre.

#### PARAPLOWING IN RATOON SUGARCANE

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Three experiments were conducted on two histosols (Pahokee muck and Torry muck) and a spodosol (Immokalee-Basinger association) to determine if paraplowing would increase ratoon cane yields. The paraplow provided good breakup of the different soils which should have improved drainage. Soil penetrometer measurements were collected during the summer growth period after all field equipment operations were over. Fuel requirements of the paraplow and of a conventional tillage treatment used by U. S. Sugar Corporation were determined. Tonnage yields were determined at harvest for each field. It appeared that paraplowing increased tonnage yields on Pahokee muck but decreased yields on the mineral soil. The yield decrease observed on the mineral soil may have occurred because of drought during spring.

#### YIELD EFFECT OF SUGAR CANE SMUT INFECTION IN FLORIDA

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New Hope Sugar Cooperative, Pahokee, Florida

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Sugarcane smut, Ustilago scitaminea H. Syd., is a major disease in Florida and many other regions where sugarcane is grown. The major objective of this study was to quantify yield losses due to smut under field conditions in Florida from the plant-cane through the second-ratoon crop. An additional objective was to compare the performance of four clones, CP 72-1210, CP 73-1547, CP 75-1091, and CP 57-603. These clones were chosen to represent smut susceptibilities of resistant, moderately susceptible, susceptible, and highly susceptible, respectively. To obtain different smut levels within each clone, seedcane was either heat treated and fungicide treated or inoculated by immersion in a suspension of viable smut teliospores. Smut levels were quantified by counting sori (whips) and by removing whips and weighing them. Both cane and sugar yields were reduced linearly by increased smut levels. Removing smut whips from infected plants in May and June of each growing season did not alter the effects of the disease on final yield characteristics. Smut levels from 0 to 6,265 whips per hectare reduced sugar yields from 10.22 to 6.37 tonnes per hectare. Masses of dried whips from 0 to 1.15 kg per hectare reduced sugar yields from 10.11 to 7.42 tonnes per hectare. The model using number of whips had less variability than the model using whip mass. This experiment was conducted on what is considered a "warm-land" sugarcane location in Florida. In addition, all three harvests (plant-cane through second-ratoon) were late in the harvest season (February or March). Under these conditions, CP 72-1210 had significantly higher sugar yields than all other clones, regardless of smut treatment.

PATH-COEFFICIENT ANALYSIS OF PLANT CANE  
YIELD COMPONENTS IN SUGARCANE

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Since many traits are correlated because of a common association with other traits, it is useful to separate this association into both direct and indirect causes. Path-coefficient analysis provides a useful method of separating direct and indirect associations among traits.

Path-coefficient analyses were used in determining the relative contributions of the yield components stalk number, stalk height, stalk diameter, density and fiber, to stalk weight, GSK (grams sugar per kg cane), TCH (tons cane per hectare) and SPH (kg sugar per hectare). Eighty-three unreplicated LCP 1986 assignments were used to determine the relationship of stalk weight and its components while 80 randomly selected clones (four clones from each of twenty crosses), replicated three times, were used to evaluate the relationship of GSK, TCH and SPH and their components. Genotypic correlations were calculated from variance and covariance components derived from the SAS GLM procedure using the MANOVA statement.

The evaluation of direct effects for stalk weight and its components showed stalk diameter to be ten times more important than stalk height and density in determining stalk weight. Fiber, with a direct effect of .002, was of little or no importance in its relationship to stalk weight. Stalk number, stalk height, stalk diameter and density, the yield components of TCH, had direct effects of 0.826, 0.298, 0.326 and 0.064, respectively. In selecting clones for high TCH, stalk number should be given greatest consideration, followed by equal consideration for stalk height and stalk diameter. Density contributed only slightly to TCH; hence, its consideration in selection for yield should be minimized. The indirect effect of stalk diameter via stalk number on TCH was -1.107; thus, a compromise must be attained when selecting clones for stalk diameter.

GSK and TCH exhibited relatively large, positive, direct effects on SPH, scoring 0.354 and 0.894, respectively. The indirect effects of GSK via TCH and TCH via GSK on SPH were positive, scoring 0.117 and 0.046, respectively. Therefore, selection of clones high in GSK and TCH should increase SPH.

INOCULATION OF UPRIGHTS TISSUE-CULTURE PLANTLETS  
OF SUGARCANE WITH TELIOSPORES, SPORIDIA, OR MYCELIUM  
OF USTILAGO SCITAMINEA

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Experiments were designed to compare the infections of five inocula from sugarcane smut (Ustilago scitaminea Sydow). The inocula included teliospores, sporidial cultures of two mating types + and - (separately and together) and mycelium produced in culture from combining the sporidial mating types. The inocula were applied by brush to the buds of uprights of sugarcane variety L 62-96 from which the outmost scale leaves were removed the day before inoculation. After inoculation, the uprights were kept in a moist chamber for two days before transfer to the greenhouse. The inocula were also applied to tissue-culture plantlets of CP 65-357 and CP 72-356. The plantlets were reproduced by the rapid-regeneration process and were still in tissue-culture jars on Murashige-Skoog medium. To inoculate the rooted plantlets, the youngest of three leaves was cut just above the dewlap, and the inocula was applied with a loop to the junction of the cut leaf blade and the next lower leaf. After four days in an incubator at 30° C, the inoculated plantlets were transplanted and grown in the greenhouse. The incidence of smut whips appeared earlier on both uprights and plantlets when inoculated with mycelium or the mixture of compatible sporidia than when inoculated with teliospores. No whips developed on uprights or plantlets when inoculated with cultures of single sporidial mating type (with one questionable exception) or on controls which were not inoculated. Use of sporidial and mycelial cultures as inoculum appears to offer the advantage of pure culture and an improved infection rate compared to teliospores under these experimental conditions.

COMPARISON OF FOUR DIAGNOSTIC TECHNIQUES FOR  
DETECTING CLAVIBACTERXYLI SUBSP. XYLI  
IN SUGARCANE WITH RATOON STUNTING DISEASE

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Four diagnostic techniques, phase-contrast microscopy (PCM), a fluorescent-antibody staining procedure (FAS), and the enzyme-linked immunosorbent assays, dot-blot (DB) and tissue blot (TB) were used to detect Clavibacter xyli subsp. xyli in sap extracts from stalks of five sugar cane cultivars, CP 72-1210, CP 63-588, CP 70-1133, CP 74-2005 and CP 65-357, with ratoon stunting disease. The third and ninth internodes above ground of two stalks from ten plants of each cultivar were examined. The TB, DB, and PCM techniques detected 94.7 percent, 91 percent, and 87.8 percent respectively, of the samples containing C. x. subsp. xyli as determined by FAS (189 positive of 200 total samples), the most sensitive of the four diagnostic techniques. Densitometric measurements rather than visual assessment of staining intensity produced by the DB assay discerned 98.4 percent of the positive samples as determined by FAS. In addition, six of the eleven samples judged not to contain the pathogen by FAS were rated positive by densitometry when values for these samples were compared with the average reflectance value of sap collected from eight noninfected plants of each cultivar.

CHANGES IN FIBER CONTENT AND NORMAL JUICE  
EXTRACTION OF THE SUGARCANE VARIETY CP 65-357 AND ITS EFFECT  
ON THE ASSIGNED MILLING QUALITY OF CANDIDATE VARIETIES

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During the infield stage of the sugarcane (Saccharum spp.) variety selection program at Houma, Louisiana, candidate varieties are subjected to complete mill tests. These tests are designed to determine the probable yield (theoretical recoverable sugar) per ton of cane of anew variety based on its fiber content and on its fiber content and normal juice extraction within year-to-year and crop-to-crop variations. To test this assumption, all data for CP 65-357 for fiber content and normal juice extraction were examined for the period 1975 to 1986. Regression analysis showed that fiber content for CP 65-357 has increased and normal juice extraction has decreased over years. This change in fiber content and normal juice extraction of CP 65-357 has made it necessary to adjust the Brix and sucrose factors used in the assignment of varietal correction factors (VCF's) to candidate varieties. Without these adjustments, the probable yield of new varieties would be overestimated.

CONCENTRATION OF DEXTRAN IN SUGARCANE JUICE  
AS AFFECTED BY POST-HARVEST MANAGEMENT

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The deterioration of sugarcane (Saccharum spp.) at harvest has long been associated with delay between cutting and milling; however, several other factors also influence the rate and extent of post-harvest deterioration. Foremost among these factors is the injury to the stalk as a result of mechanical damage, burning for the removal of trash, or frost and freezes; furthermore, environmental conditions, including temperature and humidity affect deterioration. In recent years, the concentration of dextran which is present as a result of bacterial activity, has been considered a more important indicator of cane deterioration than either pH or titratable acidity. The economic importance of dextran penalties in raw sugar production has added new urgency to determine those practices which contribute to the formation of dextran in sugarcane. In two field experiments conducted between October 10 and November 3, 1986, the effect of various post-harvest practices on the concentration of dextran in the juice was evaluated. The variety CP 65-357, in the first stubble crop, was used throughout this study. Practices included: hand vs mechanical harvesting; burning vs not burning of mechanically harvested cane; storage on the heap row vs transloader stack vs wagon storage; and, sound vs mangled stalks milled at different intervals after harvesting, burning and/or method of storage. The concentration of dextran ranged from less than 200 ppm on



soluble solids (Brix) in the juice (ASI II method) for hand-cut, fresh cane to over 18,000 ppm for mangled cane kept for five days. Results of this study showed that burning cane significantly increases the concentration of dextran in the juice when compared to unburned cane, regardless of the method of storage. Burned cane, especially early in the season when temperature and humidity are normally high, should be processed within two days since the level of dextran (greater than 1,000 ppm) found with further delay would, undoubtedly, lead to penalties for the raw sugar produced.

#### DIFFERENTIAL RESPONSE OF SUGARCANE CULTIVARS TO JOHNSONGRASS COMPETITION

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Johnsongrass, seeded at 0.6 m intervals along the line of five sugarcane cultivars in February, was allowed to grow during the plant cane crop and until June in the first ratoon crop before being carefully removed chemically. Johnsongrass increased in mass from plant cane to first stubble and more on average in CP 48-103 and NCo 310 than in CP 72-370, CP 70-321 and CP 65-357. The yield of the cultivars at harvest, as percent weed-free cane, ranged from 86 percent to 44 percent in the plant-cane crop and from 49 percent to 12 percent in the first-ratoon crop. The higher yield of CP 72-370, CP 70-321 and CP 65-357 was apparently due to the more rapid development of stands in spring while the lower yields in NCo 310 and CP 48-103 was due to the less effective competition with johnsongrass. Knowledge of the growth characteristics of a cultivar when subjected to weed competition is of value in managing weed problems on a plantation level.

#### THE EFFECTS OF SELECTION AND ENVIRONMENTS ON SUGARCANE GENETIC VARIANCE ESTIMATES IN THE PLANT CANE CROP

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The effect of selection on the source distribution of genetic variances for sugar yield components was estimated for a Louisiana sugarcane breeding population. Sugar per hectare (SPH), tons cane per hectare (TCH) and sugar content of cane (GSK) data in the plant cane crops of six synthetic subpopulations was gathered. Three of these populations were grown over two years and two locations. One was grown in the same two years and two locations with an additional location added in the second year. Another population was tested over two years and five locations, and the last was tested across three years and seven locations. These populations were previously subjected to varying levels of selection.

All data sets were balanced, and variance components for genotype and genotype by environment interaction expressed as genotype by year (GxY), genotype by location (GxL) and genotype by year by location (GxYxL) interaction variances were calculated when possible. Additionally, a separate analysis to estimate genotype by environment interaction variance (GxE) was conducted in which each year by location combination was treated as an environment. Broad sense heritabilities ( $h^2$ ) for unreplicated and replicated tests over one year and two locations and over two years and one location were calculated.

Increasing the number of test locations decreased the genotypic variance, increased the GxE variance and did not effect an error variance for SPH and TCH. These variances remained stable for GSK as the number of locations increased. Populations of commercial genotypes possessed half the genotypic variance of mildly selected populations for SPH, one-third the genotypic variance for GSK. The genetic variance of GSK diminished faster with selection than those of SPH or TCH. Consequently, for SPH and TCH, the genotypic variances were overestimated when too few environments were used.

GxYxL tended to dominate GxY and GxL, but no discernible effect of selection could be noted for any source of GxE. Heritabilities based on one year and two locations were the same as those based on two years and one location.



The persistent existence of GxYxL and indistinguishable heritabilities with varied years and locations suggests testing across locations may compensate for testing across years. However, because GxYxL is the largest source of GxE, a balanced test across years and locations is probably best.

These results suggest genotypes are being more accurately measured and selected for GSK earlier in the program than for TCH and hence SPH. The increase of GxE interaction variances for TCH and SPH with increasing environments suggests TCH could be more accurately measured earlier in the program across more locations to realize better genetic gains.

#### SOAKING AND HOT WATER TREATMENT FOR SUGARCANE BORER CONTROL ON SUGARCANE SEEDPIECES

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The main use of hot water treatments for sugarcane seedpieces has been for disease control. Different hot water treatments are known to control at least 12 sugarcane diseases. Hot water treatments and submersion in water at ambient temperature has also been reported to kill insects. However, data are lacking. When sugarcane borer infested seedpieces of varieties CP 72-355 and CP 68-1067 were submerged in water at  $52^{\circ} \pm 1^{\circ}$  C for 20 minutes, 100 percent of all larvae and pupae were killed. The mean stalk diameter of CP 72-355 was  $24.4 \text{ cm} \pm 1.6 \text{ SD}$  (Standard Deviation), while CP 68-1067 had a mean stalk diameter of  $34.6 \text{ cm} \pm 3.3 \text{ SD}$ . The mean length of stalk pieces of both varieties was  $46 \text{ cm} \pm 1.4 \text{ SD}$ . In the smaller diameter CP 72-355, it took 16 minutes for temperature to reach  $52^{\circ}$  C inside the stalk. The highest temperature reached inside the larger diameter stalk of CP 68-1067 was  $49.8^{\circ}$  C. When infested stalks were submerged in water at  $25^{\circ} \pm 1^{\circ}$  C for 24 hours, most larvae survived (90 percent). After 48 and 72 hours of submersion, survival was 48 and 16 percent respectively. However, it was observed that in the 72 hours submersion test, only three dead larvae were found inside the stalks. Many larvae were found floating and thus presumably had access to oxygen at some time. When larvae were placed in beakers and held underwater 24, 48, and 72 hours, mortality was 10, 16, and 100 percent respectively. Therefore, 100 percent mortality of sugarcane borers in sugarcane seedpieces can be achieved by submerging seedpieces in water at  $52^{\circ}$  C for 20 minutes or by holding them underwater at ambient temperature for 72 hours.

#### EVALUATING POTENTIAL SUGARCANE VARIETIES FOR RESPONSE TO SUGARCANE BORER AT THE INFIELD STAGE OF SELECTION

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A 13-year period is required to test and release a new sugarcane variety in Louisiana, beginning with the evaluation in seedling progenies to the release of a variety. In general terms, this procedure can be divided into three stages seedling evaluation, infield evaluation, and outfield evaluation. Historically sugarcane varieties were not evaluated for their response to the sugarcane borer, Diatraea saccharalis (F), until the outfield stage, or just prior to their release. This information, although useful, comes too late in the selection program to have an impact on the decision to drop or advance a variety.

Field experiments conducted in 1985 and 1986 indicate the feasibility of using artificial infestation and damage ratings to evaluate potential sugarcane varieties at the infield stage. Percent damaged internodes among the 1983 series evaluated under artificial infestation in 1985 correlated with the results from 1986 ( $r=0.61^{**}$ ). Further, visual rating of clones for their response to sugarcane borer correlated strongly to percent damaged internodes ( $r=0.60^{**}$ ). Both visual ratings and percent damaged internodes were significantly and negatively correlated to sucrose, purity, and estimated values for tonnage and sugar per acre. This information has been used to drop highly susceptible clones from the variety program prior to the outfield stage and has helped identify highly resistant clones to be used as parents in a recently initiated recurrent selection program for developing sugarcane borer resistance varieties.

## ABSTRACTS - MANUFACTURING

### OPTIONS AVAILABLE TO THE RAW FACTORY FOR IMPROVEMENT OF QUALITY AND RECOVERY

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Tate & Lyle  
United Kingdom

The imposition of severe penalties on raw sugar quality has led to increasing interest in the improvement of purification techniques in the raw house. Methods for increasing the selective extraction of sucrose or the selective removal of impurities are briefly reviewed and examples are quoted where process modifications have also led to significant increases in overall recovery.

### MILLING STUDIES

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The results obtained from three years of milling studies at Louisiana sugar factories are discussed.

The studies included numerous mill tests in which all of the cane, juice and bagasse samples available were analyzed. Brix curves and moisture profiles through the tandem were used to interpret the performance of individual mills. Cane preparation index, and the ash percent bagasse figures through the tandem were determined. The Brix of the last expressed juice was found to be a good indicator of the pol percent bagasse. Suggestions for improving milling operations are presented.

### ECONOMIES OR DISECONOMIES OF SCALE IN LOUISIANA SUGAR MILLS?

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During the past two decades, the Louisiana sugar processing (milling) industry has been characterized by rapid structural change. The number of sugar mills has declined from 42 in 1960 to 21 presently while the average capacity and the average output (raw sugar) per mill have increased significantly.

This paper measures economies of scale (size) using quantitative cost functions. A multiple least squares regression model was used to estimate the relationship between average mill output and average variable cost between 1979-1986.

### MACERATION JUICE CLARIFICATION AT CORA TEXAS

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Cora Texas is one of two sugar factories in Louisiana that have French presses to dewater the entire bagasse flow leaving the mills. Both of these factories have experienced considerable maintenance problems with the wear on the screws and flights of the presses due to abrasive field soil in the bagasse.

In the normal milling operations the field soil (ash) content of the bagasse does not change greatly following the mills whose juice goes to process. Any field soil that is removed by the mills down the tandem is returned to the preceding mill with the remaceration juice flow and is trapped in the bagasse mat. It was felt that the clarification of the remaceration mill juice would remove the field soil which would be sent directly to the mixed juice tank and be removed, while the clarified remaceration juice could be returned to the tandem.

The most noticeable improvement was the great reduction in the wear of the screw press. Also, the bagasse burned better as a result of the cleaner bagasse produced. There was also less wear on No. 4 and 5 mill rolls and trash plates.

#### THE EFFECT OF ROTATIONAL SPEED ON LOW GRADE CRYSTALLIZERS

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The ability to reduce the molasses purity in C crystallizers is dependent on the properties of the massecuite, the cooling of the massecuite and the geometry and operation of the crystallizers.

The present project was aimed at analyzing the relationship between torque on the crystallizer shaft as a function of rotational speed, molasses Brix, crystal content and temperature. The subsequent experiments were used to determine the rate of change of molasses purity with time as a function of rotational speed in the crystallizer. Different massecuites at a specific cooling rate were used in this part of the experiment.

The data presented here and the analysis of the results are used to provide suggestions for improved crystallizer operation.

#### THE CHANGING WORLD OF INSTRUMENTATION AND CONTROLS - ITS APPLICATIONS IN THE SUGAR HOUSE

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United States Sugar Corporation  
Clewiston, Florida

One very important aspect of raw sugar manufacturing is the ability to properly monitor and control both the process and equipment functions. It is in this very area that advances in micro processing and micro computer technology have provided new products which can find a wide range of application in the sugar factory.

Plant networks consisting of micro computers working with remote processors and data acquisition systems can provide management with the tools to maximize efficiency and returns. As part of these integrated systems programmable logic controllers are useful in managing repetitive tasks, as well as providing sequencing and alarming functions.

This new electronic revolution allows us to look at the process from different perspectives and provides low cost alternatives to enhance information and production in the sugar factory.

#### LOUISIANA DEXTRAN STUDIES, 1986

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Daily Haze analyses for dextran in raw sugar were supplied by 12 Louisiana factories. Results confirmed a strong dependency on weather conditions. Dextran in sugar rarely exceeded 250 MAU when daily low temperatures were below 50-55° F. But in warmer, wet weather, the average statewide was greater than 250 MAU. While all factories followed the weather-dependent pattern, there were side individual differences among factories. These differences related to geographical location, mill stoppages, and management practices.

At one factory, core lab cane juice composites from each shipper were analyzed daily for dextran by the ASI-II method. When the daily average dextran content of the juice exceeded about 1400 ppm, dextran in sugar rose above 250 MAU. As long as the average juice level was below 1400 ppm, the dextran in sugar remained below 250 MAU.

GEL PERMEATION CHROMATOGRAPHY  
OF SUGARCANE PRODUCTS

Michael Saska and Y. Oubrahim  
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Gel permeation chromatography was used to detect and characterize the native sugarcane biopolymers in a variety of products, such as juice, raw sugar and molasses. Correlations are presented with ASI II and hazed dextran analyses and information is discussed about the dextran partition in the manufacturing process.

ON-LINE HPLC ANALYSIS FOR SUCROSE

Ron Sutton  
ProMonix  
Milford, Massachusetts

A new online analyzer for sucrose is described, and the accuracy and precision of results obtained are discussed.

HPLC ANALYSIS OF RAW SUGAR:  
A RAPID METHOD

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In the past, direct HPLC analysis of raw sugars has not been practical for factory use. Available methods have required post-column derivatization, or non-durable columns, or the use of organic solvents to obtain analyses of sucrose and reducing sugars.

A recently developed method, using water as a solvent, for analysis of invert in raw sugar in under eight minutes, is reported.



AMERICAN SOCIETY OF SUGAR CANE TECHNOLOGISTS  
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Nature of papers to be published:

Papers submitted must represent a significant technological or scientific contribution. Papers will be limited to the production and processing of sugarcane, or to subjects logically related. Authors may submit papers that represent a review, a new approach to field or factory problems, or new knowledge gained through experimentation. Papers promoting machinery or commercial products will not be acceptable.

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The Journal will appear at least once a year. At the direction of the Joint Executive Committee, the Journal may appear more frequently. Contributed papers not presented at a meeting may be reviewed, edited, and published if the editorial criteria are met.

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Unless the nature of the manuscript prevents, it should include the following sections in the order listed: ABSTRACT, INTRODUCTION, MATERIALS and METHODS, RESULTS, DISCUSSION, CONCLUSIONS, ACKNOWLEDGMENTS, and REFERENCES. Not all the sections listed above will be included in each paper, but each section should have an appropriate heading that is centered on the page with all letters capitalized.

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Name of the author(s), institution or organization with which he is associated, and the location should follow the title of the paper.

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The abstract should be placed at the beginning of the manuscript, immediately following the author's name, organization and location.

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Number the tables consecutively and refer to them in the text as Table 1, Table 2, etc. Each table must have a heading or caption. Capitalize only the initial word and proper names in table headings. Headings and text of tables should be single spaced. Each table should be on a separate sheet.

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EVALUATION OF SUGARCANE CHARACTERISTICS  
FOR MECHANICAL HARVESTING IN FLORIDA

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ABSTRACT

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## **PRESIDENT'S MESSAGE - FLORIDA DIVISION**

**Tirso M. Carreja**  
Sugarcane Growers Cooperative of Florida  
Belle Glade, Florida

The Florida sugar industry has completed the best crop in its history. Helped by two consecutive years without freeze and in spite of a drought in the middle of the cane growing season, the industry imposed the following three new records for Florida: most sugarcane ground, most raw sugar produced and highest sugar yield from sugarcane, all for one season.

The crop season began October 20 and ended March 22 with a total of 155 crop days. In that period of time, we ground 13.74 million short tons of sugarcane, produced 1.51 million short tons of sugar raw value, with a yield of 10.84 percent. We also produced 90.14 million gallons of final molasses 79.5 Brix.

Florida has kept the pace as the number one sugar producer in the United States thanks to the dedication and hard work of individual people and organizations; from agricultural researchers, to the executives that make the final decisions. All of them working together have helped to achieve this goal.

To sell and ship the raw sugar and final molasses produced, the Florida sugar industry depends on two cooperative organizations: The Florida Sugar Marketing and Terminal Association, Inc. and the Florida Molasses Exchange, Inc.

The Florida Sugar Marketing and Terminal Association, Inc. was formed in 1978 by five raw sugar producers, which built a deep-water loading facility at the Port of Palm Beach, with an initial expectation of shipping 250,000 tons per year to markets that could not be economically reached by rail or truck. With the completion of this terminal in 1979, the Florida industry was able to sell to all U.S. refiners and trade houses. This, along with increased sugar storage capacity enabled the processors greater flexibility in achieving better sugar prices as they were no longer restricted to dealing with a limited number of buyers who insisted on discounts to the market.

In recent years, this facility has also enabled the Florida industry to resist some of the onerous quality terms imposed by some refiners, in the form of the revised dextran and color tests.

The success of the terminal is best measured by the volume actually shipped through it. Quantities have increased each year, and by the end of 1987 the Florida industry had shipped 5,486,571 tons in nine years of operation, culminating with just over one million tons loaded out in calendar year 1987 alone.

The Port of Palm Beach the Florida Molasses Exchange, Inc. also operates, on behalf of all the Florida sugar industry, a deep-water molasses export terminal that has grown from 6,500 tons holding capacity at construction in 1973 to 40,000 tons currently, with plans to expand to 60,000 tons during Autumn, 1988. Approximately half of Florida's 500,000 tons molasses production is moved by highway semi-trailer to the terminal for subsequent shipment to feed grade molasses buyers in Europe and Canada. In conjunction with distributor's highway trailers and a combined fleet of over 100 jumbo rail tank cars, the port terminal enables the Florida industry to maintain a balanced marketing program.

We are also members of the Florida Sugar Cane League, and rely upon it to assist the sugar industry in subjects related with environmental, legislative, public relations, agriculture research and others subjects common to the industry.

During the past year, the Florida sugar industry has addressed many concerns regarding Florida's environment. The industry, through the Florida Sugar Cane League, formed the Environmental Quality Committee in 1968 in order to address both air and water issues, and has had to continually call upon its member's expertise to protect agricultural interests.

Water quality and quantity issues have been in the forefront. With the passage of the Surface Waters Improvement Management Act (SWIM) in the 1987 state legislature, emphasis has been directed to Lake



Okeechobee and the downstream impacts of runoff on the water conservation areas and Everglades National Park. The industry has taken the lead in the development and support of research on air and water quality in the Everglades Agriculture Area, Lake Okeechobee and surrounding areas. We will continue to play an active role in finding solutions to balance the water needs of South Florida's fragile ecological system.

In an effort to raise funds needed to conduct further water quality research, growers in the Everglades Agricultural Area have volunteered to tax themselves by forming a special taxing district. Although we have encountered many bureaucratic roadblocks, we are confident that our proposal will become a reality.

In addition to water programs, the industry conducts one of the largest private air monitoring networks in the state. The industry is also experimenting with more advanced monitoring such as PM-10's and a dichotomous sampler that be used in the future.

Presently the sugar industry looks good. We are almost in the middle of a five year sugar legislative program that allows the sugar industry to survive, but at no cost to the government. We have to remember that. Now if we look back ten years and evaluate the industry and market trends, we must start worrying about the near future.

In 1978 the U.S. market size was 14.0 million tons of nutritive sweeteners. Sucrose's share was 10.2 million tons (refined basis), with 5.5 million produced from cane and beet and 4.7 million from offshore suppliers. The other 3.8 million went to corn sweeteners and various nutritive sweeteners.

In 1987 we find a very difficult situation. Total market size is 16.1 million tons of nutritive sweeteners. Sucrose share is only 7.6 million tons (refined basis); 6.6 million from cane and beet, and 1.0 million from offshore suppliers. The other 8.4 million went to corn sweeteners and various nutritive sweeteners.

As we can see, total nutritive sweeteners consumption in the U.S. has increased 2.2 million tons in ten years, while the sucrose consumption has decreased 2.6 million tons in the same period. This means, that not only did we lose 2.6 million tons of the existing market, but also that we did not receive any benefit from the growth in the market.

In 1987, for the first time in the last ten years, the sucrose consumption increased compared with the year before, and it looks like liquid corn sweeteners have reached market maturity. But the corn sweetener producers are working very hard developing a crystalline high fructose to compete in price and quality with sucrose. That is a threat that we can not ignore.

Until now domestic production hasn't been affected. We have increased our sucrose production by 1.1 million tons in spite of 2.6 million tons of decrease in consumption. The 3.7 million tons net decline have been a loss to the offshore quota. But the offshore quota is almost drained out, and if the present trend is followed, by 1991 we may have no tool to effectively administer the existing sugar program as well as making it more difficult to achieve a new sugar program in the next Farm Bill.

We have to prevent this situation from becoming a reality. We have to work to increase the sucrose consumption and control the sugar marketing. I know that it is something very easy to say, but very difficult to carry out.

The best way to increase the sucrose consumption is by using advertising and promotion. We are living in a marketing society and the industry has to become more marketing oriented. We know all about that, because the sugar industry has been under attack for many years using the myth that sugar is dangerous to our health. This myth has gone so deep in the mind of the people, that many manufacturers advertise their products with slogan "sugar free". It is time to go back to the people and tell them the truth; that sucrose is pure, 100 percent natural and the "gold standard" in sweeteners. We are now in a competitive market where we have to advertise our product if we want it to survive. The advertising is expensive, but it will yield dividends.

Besides advertising, we have to control the domestic sweetener marketing in the country. We cannot continue the present trend of increased production in a limited market. We have to work hard together with other nutritive sweetener producers to come to an agreement, and work on a legislative program that will limit domestic sweetener marketing in the country. If we don't do this now, in the future we will produce more sugar



than is consumed in the country leading to a loss of the Sugar Program. And the sucrose "below production cost" dumped by foreign sugar producer countries, will come directly into the U.S. market and will deeply hurt the U. S. sweetener producers. I know that many of you do not like to hear about marketing quotas, but somebody, someday must take the first initiative.

Think about it, but please do not wait too long.

## PRESIDENT'S MESSAGE - LOUISIANA DIVISION

Roland Talbot  
Ronald Talbot Farms  
Thibodaux, Louisiana

On behalf of the Louisiana division of the American Society of Sugar Cane Technologists, I want to thank the Florida division for hosting the Eighteenth Annual Joint Conference in Clearwater, Florida.

The 1987 Louisiana sugarcane crop began where the 1986 crop ended: that is, fields having deep ruts filled with water from the excessive rains that fell throughout the harvesting season of the 1986 crop. The first priority was to drain the fields as soon as possible. The cane belt experienced several days with either a light freeze or frost which resulted in the loss of some terminal buds. Rainfall delayed much of the field work up to mid-April when fields became dry enough to begin to cultivate, apply fertilizer and spray for weed and grass control.

The 1987 crop produced 6,675,000 short tons of sugarcane and was processed into 740,000 tons of raw value sugar. The 265,000 acres of cane were delivered to 21 mills before Christmas. The Louisiana mills grinding operations lasted an average of 64 days, compared to 70 days for 1986. There was 11 percent less cane produced and 11 percent more sugar processed in 1987 than 1986. When warehouse sugar inventories are finally delivered to refiners, this will be either the second or third largest sugar crop produced in Louisiana. Mill production average for raw value sugar per ton in 1987 was 222 pounds compared to 181 pounds for 1986, an increase of 23 percent.

Climatic conditions for the 1987 crop had a significant bearing in the record high yield. The Louisiana Gulf Coast was never threatened by hurricanes and the weather fronts that came through the cane belt were generally not violent. The results of these conditions were an erect sugarcane crop which made harvesting cleaner cane a pleasant experience.

Comparing records of climatic conditions for 1986 and 1987 from the USDA Experiment Station in Houma should help answer the question: Why a 23 percent increase in sugar per ton yield? Rainfall during the months of May and June of 1987 totaled 23.6 inches compared to 11.4 inches for May and June of 1986, or a 106 percent increase in rainfall for 1987. For the same period of 1987 there were 39 days with rainfall compared with 27 days in 1986, or a 44 percent increase in days of rainfall for 1987. These conditions prevented some growers from completing their fertilization operations and, in most cases, prevented the completion of cultivation and layby operations. These wet conditions and reduced sunlight resulted in a reduction in the number of tillers which were able to survive and turn into millable stalks.

The harvesting season also had climate conditions which contributed to the record yield. Rainfall recorded for October through December 1987 was 8.1 inches compared with 1986 which was 15.8 inches, or a decrease of 48 percent to 1987. Low humidity readings for the three harvesting months for 1987 averaged 42 percent compared to 76 percent for 1986.

The cooler and dryer weather conditions of September and October resulted in cane maturing sooner than normal. Growers treating cane with Polado also experienced increases in sugar per ton over untreated cane. The lower humidity resulted in a more complete burn of cane leaves and grasses. With drier fields, little or no mud was delivered to mills. Little or no dextran problems were encountered due to the cooler and drier than normal conditions. Each of these climatic conditions had its effect on the 1987 crop. The results was the phenomenal record of producing more pounds of sugar per ton than anytime in the 150 year history of the Louisiana sugarcane industry.

Through the efforts of the our sugarcane variety research program, a new cane variety, CP 79-318, was released to the producers in 1987. This variety was jointly developed and released by the cooperating agencies, the Agricultural Research Service of the U.S. Department of Agriculture, the Louisiana Agricultural Experiment Station of the Louisiana State University and The American Sugar Cane League. According to scientists from the three agencies CP 79-318 should yield as well as CP 70-321 and CP 65-357 in both tonnage and sugar per ton.

The increased use of the two-row harvesters and loaders with mechanical cane pilers has helped contribute to the outstanding sugar per ton yield. The development and use of the two-row loader will further enhance the quality of cane delivered to the mills in the future. Most of the cane planted in Louisiana is now planted with mechanical cane planters, even though efficiency has yet not been achieved. Cane planters basically have two problem areas that are in need of engineering research. More cane is planted than necessary and damage to seed cane needs to be reduced. Many mechanical planters are planting in excess of 56,000 eyes per acre with approximately four percent damaged by cutting and loading operations and approximately eight percent damaged by mechanical planters. Planting over 30,000 eyes per acre does not increase final stands or yield. If mechanical planters were more efficient, there could be a 40 percent decrease in cane used for seed.

Processors, cooperating with the Audubon Institute, will have to be more cost-efficient, reduce loss time by improving equipment performance and with computer technology, automate mill operations when practical to eliminate human error. Research is needed to develop a quick, reliable test for dextran in cane juice and methods for dextran control and elimination.

The Reagan Administration has not given up its desire to change the sugar program by lowering loan rates from 18 to 12 cents per pound. With import quotas reduced to 750,000 tons and blended sugar approaching 900,000 tons, entering the United States outside the import quotas system, our successful "no-cost" sugar program is threatened. Organizations represented by some of the largest sugar corporations in America are opposing the sugar program. Only the self-interest for profit is the justification for their opposition.

The challenge in the future will be to preserve a viable domestic sugar industry. The first challenge will be to prevail on the members of congress and assure the consumers that sugar can be purchased at reasonable, stable prices and changing the sugar program will not be in their best interest. Many consumers believe that if no sugar program existed they could purchase sugar at the so-called "world price" of eight cents a pound. That myth would soon turn to a deplorable reality when sugar prices would escalate without a domestic sugar industry.

We will have to be more aggressive in marketing our product. Competition in the sweetener industry is fierce and backed with advertisement programs costing millions of dollars. Numerous consumers also believe that sugar is harmful and should be not be consumed. Sugar is a safe product. It is the highest quality sweetener, pure and 100 percent natural. It is long past time for our industry to change its thinking. We must change from a passive defense to an active offense before its too late. Now is the time for the sugar industry to seize the opportunity to work collectively to market our product.

The people of the Louisiana sugarcane industry have survived because of the determined character of the people that make up this industry. Adversities are common, they range from the freeze that happens too late in the spring or too early in the fall. The rains that fall when a drought would be more beneficial, a drought when the crop is withering for need of rain, high winds and rain that flatten cane to the ground, etc. Nevertheless, after each year we bounce back with renewed enthusiasm ready to produce another cane crop.

The Louisiana sugarcane industry is grateful to those, past and present, who have helped and supported our industry by participating at joint meetings of the American Society Technologists. Without the support of our universities, dedicated personnel of the USDA, Louisiana State University, The Cooperative Extension Service and the American Sugar Cane League, the knowledge needed to survive in an ever-increasing competitive sweetener market, could be the difference between survival and extinction. This industry would certainly not survive if it were not for the unanimous support of our congressional delegation and our alert lobbyists. Through the effort of the American Sugar Cane League, congressmen from other states have visited our industry and left with a better understanding of the need of having a viable domestic sugar industry for the good of the taxpayer, the consumer and the industry.



## EVALUATION OF TRAITS ASSOCIATED WITH RESISTANCE TO SUGARCANE SMUT CAUSED BY *USTILAGO SCITAMINEA*<sup>1</sup>

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Plant Pathology and Crop Physiology Department  
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### ABSTRACT

Resistance to smut, caused by *Ustilago scitaminea*, was evaluated in 15 hybrid clones of *Saccharum* with smut reactions ranging from resistant to highly susceptible. No consistent association was found between smut infection level and bud traits including length, width, length x width, shape, flange, groove, germination type, germination times, and shoot growth rates. In two clones, CP 65-357 and CP 74-383, inoculation of plants with initial shoot lengths up to 6 cm resulted in high smut infection levels, whereas inoculation of ungerminated buds or plants with longer shoots resulted in low infection levels. Resistance to systemic infection was detected in plants of resistant and susceptible clones following wound inoculation.

### INTRODUCTION

Sugarcane smut, caused by *Ustilago scitaminea* Syd., is an important disease of interspecific *Saccharum* hybrids worldwide (1). Infected sugarcane stools contain grass-like, unmillable shoots which produce a long, unbranched, terminal "whip" at the apex. Billions of fungal spores are produced and released from each whip (16). Yield losses usually increase with successive ratoons and can be very severe in susceptible cultivars.

Resistant cultivars have proven to be the most effective measure to reduce the incidence and severity of smut. Hence, breeding and selection for smut resistant clones receives major emphasis in sugarcane breeding programs wherever the disease occurs (4,5,8,9,18). Smut resistance levels are typically evaluated by dip-inoculating stalks of clones in smut spore suspensions, planting the stalks, and comparing the levels of infection that occur in different clones during the growing season. Repeated trials are necessary to reliably determine and evaluate clone smut reactions. This is a time consuming and expensive process requiring large amounts of space. Therefore, research has been conducted to determine if any plant characteristics are consistently associated with resistance to smut (2,11,12,17).

Several bud morphological traits and growth characteristics have been reported to be associated with susceptibility to smut (11,17). These traits include large bud size, triangular bud shape, absence of a bud flange, presence and depth of a bud groove, apical type of bud germination, rapid bud germination rate, and rapid initial shoot growth rate. In addition, research has attempted to determine shoot lengths at which germinated buds become resistant to infection (3). It has been suggested that bud traits are variable under different environmental conditions (8,11,17); therefore, confirmation of these associations with more cultivars in different environments is needed.

Most of the research to determine the nature and mechanisms of expression of smut resistance has focused on bud characteristics or resistance to infection. However, consistent differences in the expression of disease between cultivars have been observed, and different types of resistance to sugarcane smut have been postulated (6,7,10). A pre-infectional type of resistance revolves around a barrier to initial infection represented by the bud scales (2,12). Post-infectional types of resistance may prevent the establishment of infection and affect the extent of fungal colonization and disease expression (6,10).

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<sup>1</sup>Approved for publication by the Director of the Louisiana Agricultural Experiment Station as manuscript number 88-38-2404.



The first objective of this study was to evaluate sugarcane cultivars in the Louisiana breeding population for the association of smut resistance with selected morphological traits and growth characteristics. The second objective was to evaluate cultivars for the expression of what has been termed post-infectious resistance to smut (7,10).

## MATERIALS AND METHODS

Fifteen sugarcane clones selected from the Louisiana sugarcane breeding population, L 65-69, CP 65-357, CP 66-346, CP 67-412, CP 70-330, CP 72-355, CP 72-356, CP 72-370, CP 73-308, CP 73-351, CP 74-383, CP 76-340, CP 77-310, CP 77-407, and CP 77-413, were chosen to study the association between bud morphological traits, germination, and growth parameters and resistance to smut.

### Smut ratings of tested clones

During September 1985, three 6-stalk replicates of each clone were dipped for 10 minutes in a freshly prepared smut spore suspension containing  $5 \times 10^6$  spores/ml. The three replicates of each clone were planted in a randomized block design in single row plots 2.7 m in length with 0.9 m alleys between plots.

The number of smut-infected stalks and the total number of stalks in each plot were recorded nine months after planting. The overall smut infection percentage of each clone was calculated by averaging the smut infection percentage over three replicates. The level of smut resistance in each clone was rated on the basis of comparisons of overall smut infection levels with infection levels in clones with known smut reactions (CP 72-356, resistant; CP 65-357, moderately susceptible; and CP 73-351, highly susceptible). Based on these comparisons, clones with an overall smut infection percentage less than 11% were rated as resistant (R). Clones with smut infection percentages ranging from 11-22% and greater than 22% were rated as moderately susceptible (MS) and highly susceptible (HS), respectively.

### Bud morphological characters

During October 1986, 40 nodes in the middle portions of four stalks of each of 15 clones were chosen for measurements of bud length, width, and shape and observation for bud germination type and the presence of a bud flange and groove. Bud length x width was calculated and used as an approximation of bud size. The degree of correlation between bud length, width, length x width and the inoculation test smut infection percentage was determined by regression analysis. Since bud shape, groove, flange, and type of bud germination (15,17) are not traits with continuous variation, a contingency chi-square ( $X^2$ ) test (14) was used to analyze associations between these traits and smut infection percentages of R, MS, and HS cultivars.

### Bud germination type, time and shoot growth rates

During October 1986 (Experiment I), 15 two-bud cuttings were obtained from the middle sections of stalks of each clone, and the upper bud of each cutting was excised. All cuttings of each clone were then dipped in a mixed fungicide suspension containing 0.1 g a.i./liter benomyl (0.2 g 50% wettable powder) and 0.7 g a.i./liter captan (1.4 g 50% wettable powder) for 20 minutes and then placed in a plastic box containing wet paper towels which served as a germination chamber. Boxes were covered with black plastic and incubated at 25 C. The time required for bud germination, the type of germination, and shoot growth rate were recorded for each clone. Bud germination time was the number of days required for the first emergence of a shoot initial from the bud. Bud germination was classified as apical, subapical, or dorsal for individual buds (17) and compared among R, MS, and HS clones with a contingency chi-square analysis. Growth rate was calculated from the time visible signs of germination were observed until a shoot developed to a length of 10 cm. Correlations of bud germination time and shoot growth rate with smut infection percentages were determined for each clone. The experiment was repeated during November 1986 (Experiment II), except clone CP 76-340 was not included.

### Shoot length-susceptibility relationship

During November 1986, 135 and 170 one-bud cuttings were taken from the middle portions of stalks of two sugarcane cultivars, CP 65-357 and CP 74-383, respectively, and used to determine the effect of shoot length

on susceptibility to smut infection. All cuttings of each clone were dipped in a mixed fungicide suspension as described previously. They were then washed, dried and both ends were sealed with wax.

Thirty and 32 cuttings of CP 65-357 and CP 74-383, respectively, with ungerminated buds were dip-inoculated for 10 minutes in a smut spore suspension containing  $5 \times 10^6$  spores/ml. After being incubated in germination chambers at 30 C for 18 hours, they were washed with a 5% sodium hypochlorite solution to kill external smut spores and planted in 10-cm diameter clay pots in a sterile soil, sand, peat moss mix (3:1:1,v:v). The remaining cuttings of each cultivar were germinated in chambers covered with black plastic. Various numbers of germinated cuttings (Table 5) with shoot lengths ranging from 0.1-6, 6.1-12, 12.1-18, and 18.1-24 cm were dip-inoculated, incubated, surface sterilized, and planted as described previously.

Primary shoots produced from inoculated cuttings of each clone were harvested such that four lateral buds were left on the cuttings in the pots. The growing point of each cutting was then stained with trypan blue to detect the presence of *Ustilago scitaminea* mycelium (13). Growing points were stained, mounted on glass slides, coverslipped, and examined under a compound microscope at 250X for the presence of fungal mycelium. If mycelium was not detected in the growing point of the primary shoot, then secondary shoots developing from lateral buds were examined. A plant developing from an inoculated cutting was regarded to be infected if mycelium was detected in any meristematic tissue.

#### Systemic infection evaluation

Fifteen clones (Table 6) were chosen for evaluation of resistance to systemic infection in individual plants. Six clones were previously rated as resistant in breeding program smut inoculation tests (unpublished), four clones were rated as moderately susceptible, and five clones were highly susceptible. Generally, 20 one-bud cuttings of each clone were selected from the middle portions of stalks and inoculated with smut spores using a wound-paste inoculation technique (9). Ungerminated buds were pin pricked with a needle to make six wounds and then painted with a smut spore paste. After inoculation, cuttings were incubated in black plastic bags containing wet paper towels for two days at room temperature and then planted in flats in sterile soil, sand, peat moss mix. When inoculated buds developed into shoots with three to four emerged leaves, they were transplanted into plots during June 1985 with distance intervals of 0.6 m between plants. Data recorded for each clone included the number of smut-free stools, the number of smut-infected stools, the total percentage of smut-infected stalks, the number of stools with resistance to systemic infection (stools containing apparently smut-free as well as infected stalks), the numbers of apparently healthy and smut-infected stalks in each stool, and the number of completely smutted stools.

### RESULTS

#### Evaluation of association between bud traits and resistance to smut

In a smut inoculation test, seven clones were rated as resistant (R), four clones were rated as moderately susceptible (MS), and four clones were rated as highly susceptible (HS) (Table 1). Differences were detected between means for clones within and among resistance rating groups for bud length, width, and length x width (Table 1).

The major types of bud shape were round and ovate for R and MS clones and ovate for HS clones (Table 2). MS and HS clones did not have triangular buds, and obovate buds were not found for HS clones. R, MS, and HS clones had different bud shape frequencies (Table 2A).

The most frequent type of bud flange was medium for R, MS, and HS clones (Table 2B). The second most frequent type was small for HS clones and absent for MS clones. R, MS, and HS clones had different bud flange size frequencies. Absence of a bud groove followed by buds with shallow bud grooves had the highest frequencies for R, MS, and HS clones (Table 2C). MS clones did not have deep or very deep bud grooves. The percentage of buds with a deep bud groove was similar for R and HS clones, and only one bud with a very deep bud groove was found in a HS clone. Bud groove sizes varied among R, MS, and HS clones.

The most frequent type of bud germination was apical in R, MS, and HS clones in Exp. I (Table 3A). Dorsal and subapical types of bud germination also occurred in R, MS, and HS clones. In Exp. II, the most frequent type of bud germination was apical for R and HS clones and subapical for MS clones (Table 3B).



Dorsal bud germination was not observed. R, MS, and HS clones had different bud germination type frequencies in both experiments (Table 3).

Table 1. Comparisons of smut infection percentage means and resistance ratings with bud length, bud width, and bud length x width for 15 sugarcane clones.

Sugarcane clone	Mean smut infection percentage	Smut rating <sup>1</sup>	<u>Bud length (mm)</u>		<u>Bud width (mm)</u>		<u>Bud length x width (mm<sup>2</sup>)</u>
			Mean <sup>2</sup>	Range	Mean	Range	Mean
CP 70-330	0	R	6.8	6-8	6.0	4-7	40.8
CP 72-356	0	R	6.0	4-7	6.2	4-7	38.0
CP 77-310	0	R	7.1	5-9	6.6	5-9	47.6
CP 67-412	1	R	5.8	5-7	6.6	5-8	38.5
CP 72-370	1	R	8.5	6-12	7.8	6-11	68.0
CP 66-346	2	R	9.7	8-12	6.9	6-9	67.7
CP 72-355	5	R	12.2	8-18	8.9	6-13	111.0
CP 65-357	12	MS	5.7	4-7	5.8	4-7	33.3
L 65-69	17	MS	6.3	6-7	5.5	5-7	34.8
CP 77-413	21	MS	8.1	6-10	7.1	6-8	57.8
CP 73-308	21	MS	7.3	5-10	7.0	5-10	52.0
CP 73-351	31	HS	6.8	4-8	5.5	4-8	38.0
CP 77-407	37	HS	10.5	7-15	9.5	7-13	101.2
CP 76-340	43	HS	7.7	7-10	7.4	6-8	57.4
CP 74-383	57	HS	7.4	5-9	5.7	5-8	42.3
LSD <sub>0.05</sub> =			0.55		0.44		7.53

<sup>1</sup> R=resistant, MS=moderate susceptible, and HS=highly susceptible smut reactions.

<sup>2</sup> Mean values were based on 40 measurements. Means within a column were analyzed by Fisher's Protected LSD.

Differences in the mean number of days required for bud germination were detected between clones within and among different resistance rating groups in both experiments (Table 4). In addition, the means for number of days required for bud germination were different between Experiment I and Experiment II for all seven R clones, two of four MS clones, and one of four HS clones. There was no consistent pattern in the changes in times required for bud germination between experiments.

Differences in the mean growth rate (mm/day) were detected between clone means within and in different resistance rating groups in both experiments (Table 4). The growth rate decreased for 14 clones in Experiment II, and the decrease was significant in four of seven, two of four, and two of three R, MS, and HS clones, respectively (Table 4).

Correlation coefficients between clone smut infection percentages and bud length (0.08), bud width (-0.01), and bud length x width (0.04), were all nonsignificant. In Experiments I and II, clone smut infection percentages were also not significantly correlated with the time required for bud germination ( $r = -0.25$  and  $0.08$ , respectively) or initial shoot growth rates ( $r = -0.11$  and  $-0.09$ , respectively).

Table 2. Contingency chi-square analysis of associations between smut reactions and A. bud shape, B. bud flange, and C. bud groove in 15 sugarcane clones.

A. Bud shape

Smut reactions of tested clones <sup>1</sup>	Percentage of buds with each bud shape type					Chi-square value <sup>2</sup>	
	Round	Oval	Obovate	Ovate	Triangular	Value (X <sup>2</sup> )	Probability
R	44.0	2.5	6.7	36.6	10.2	142.6	<0.001
MS	53.3	4.9	2.5	39.3	0.0		
HS	10.0	13.1	0.0	76.9	0.0		

B. Bud flange

Smut reactions of tested clones	Percentage of buds with each bud flange type				Chi-square value	
	Absent	Small	Medium	Large	Value (X <sup>2</sup> )	Probability
R	1.1	37.3	47.5	14.1	127.2	<0.001
MS	31.2	13.1	54.1	1.6		
HS	5.0	25.6	60.0	9.4		

C. Bud groove

Smut reactions of tested clones	Percentage of buds with each bud groove type				Chi-square value	
	Absent	Shallow	Deep	Very deep	Value (X <sup>2</sup> )	Probability
R	50.7	31.0	18.3	0.0	38.9	<0.001
MS	74.6	25.4	0.0	0.0		
HS	55.0	22.5	21.9	0.6		

<sup>1</sup> Seven clones were resistant, four were moderately susceptible, and four were highly susceptible to smut. R=resistant, MS=moderately susceptible, and HS=highly susceptible smut reactions.

<sup>2</sup> Chi-square values calculated from actual numbers with each bud character.

Shoot length-susceptibility relationship

High smut infection percentages resulted in plants of both clones inoculated with initial shoots up to 6 cm long, whereas plants inoculated as ungerminated, intact buds developed low infection percentages (Table 5). Infection percentages then decreased to low levels in plants inoculated with initial shoots 6.1-24 cm in length (Table 5).



Table 3. Contingency chi-square analysis of association between type of bud germination and smut reactions of 15 sugarcane clones in experiments conducted during I. October and II. November, 1986.

A. Experiment I.

Smut reactions of tested clones <sup>1</sup>	Percentage of buds with each bud germination type			Chi-square value <sup>2</sup>	
	Dorsal	Subapical	Apical	Value (X <sup>2</sup> )	Probability
R	24.5	16.7	58.8	10.1	<0.05
MS	23.3	11.6	65.1		
HS	5.4	21.4	73.2		

B. Experiment II.

Smut reactions of tested clones	Percentage of buds with each bud germination type			Chi-square value	
	Dorsal	Subapical	Apical	Value (X <sup>2</sup> )	Probability
R	0.0	48.4	51.6	19.3	<0.001
MS	0.0	69.8	30.2		
HS	0.0	22.0	78.0		

<sup>1</sup> Seven clones were resistant, four were moderately susceptible, and four were highly susceptible to smut. R=resistant, MS=moderately susceptible, and HS=highly susceptible smut reactions.

<sup>2</sup> Chi-square values calculated from actual numbers with each bud character.

Evaluation of resistance to systemic infection

Smut infections developed in plants of two of six R clones, four of four MS clones, and five of five HS clones following wound inoculation (Table 6). The proportion of the total number of stools showing a smut infection was 11% and 20% for the two R clones compared to total percent stalk infection levels of 2% and 6%, respectively (Table 6). The infection levels for the MS clones ranged from 35-100% and 26-100% for stools and stalks, respectively, and infection levels for the HS clones ranged from 78-100% and 66-97% for stools and stalks, respectively. The proportion of the smut-infected stools of each clone that contained at least one apparently smut-free stalk (stools with resistance to systemic infection) was 100% for the two R clones and ranged from 0-71% for both MS and HS clones (Table 6). The mean percentage of infected stalks per stool with resistance to systemic infection ranged from 15-29%, 75-92%, and 60-93% for R, MS, and HS clones, respectively (Table 6).

## DISCUSSION

None of the traits evaluated in this study including bud length, bud width, bud length x width, bud shape, bud groove, bud flange, time required for bud germination, type of bud germination, and initial shoot growth rate were consistently associated with smut resistance. These results indicate that none of these traits, as measured, can be used to reliably identify resistant or susceptible clones.

Table 4. Comparisons of smut infection percentage means and resistance ratings with length of time required for bud germination and initial shoot growth rates for 15 sugarcane clones in experiments conducted during I. October and II. November, 1986.

Sugarcane clone	Mean smut infection percentage	Smut rating <sup>1</sup>	Time (days) required for bud germination <sup>2</sup>		Mean growth rate <sup>3</sup>	
			Experiment		Experiment	
			I	II	I	II
CP 70-330	0	R	4.9 <sup>4</sup>	2.6** <sup>5</sup>	9.6	8.9
CP 72-356	0	R	4.4	2.8**	9.8	9.6
CP 77-310	0	R	1.9	3.1**	10.4	8.2
CP 67-412	1	R	4.6	2.4**	9.4	10.0
CP 72-370	1	R	2.3	3.6**	12.2	9.2**
CP 66-346	2	R	2.1	3.1*	10.2	7.8**
CP 72-355	5	R	2.6	4.0**	13.1	8.1**
CP 65-357	12	MS	5.1	3.5*	10.3	9.8
L 65-69	17	MS	4.1	3.6	9.5	7.4*
CP 77-413	21	MS	2.0	3.1**	10.0	9.5
CP 73-308	21	MS	2.9	3.4	12.1	7.7**
CP 73-351	31	HS	4.2	3.4	10.1	8.9
CP 77-407	37	HS	3.0	4.1	10.6	7.7**
CP 76-340	43	HS	1.7	- <sup>6</sup>	9.8	-
CP 74-383	57	HS	1.8	3.0**	13.6	8.5**

LSD<sub>0.05</sub> = 1.05 0.82 1.44 1.23

<sup>1</sup> R=Resistant, MS=moderately susceptible, and HS=highly susceptible smut reactions.

<sup>2</sup> Mean of time (days) required for bud germination for 15 buds of each clone.

<sup>3</sup> Means for initial shoot growth rates (mm/day) from germinated buds of each clone were determined from the time (days) required for shoot lengths to reach 100 mm.

<sup>4</sup> Clone means were generally based on 15 measurements. Means within experiments were analyzed by Fisher's Protected LSD.

<sup>5</sup> Means for tested clones in Experiment I and Experiment II were compared in a t-test and some differed significantly at the P<0.05 (\*) or P<0.01 (\*\*) levels.

<sup>6</sup> Clone CP 76-340 was not available in Experiment II.

Methods used to estimate bud size have varied between studies. Waller (17) used the amount of water displaced by excised buds, and the correlation between smut incidence and increasing bud size was 0.895. Muthusamy (11) reported bud area in cm<sup>2</sup> and a correlation coefficient with smut incidence of 0.553. However, the method for calculation of bud area was not stated. Despite the differences in measurement methods used, the results of this study indicate that small bud size is not associated with smut resistance.

Correlation coefficients of 0.762, 0.796, and 0.768 were found between smut incidence and bud germination type, time to bud burst, and growth rate, respectively, in 18 clones in the study conducted by Waller (17). He concluded that dorsal germination and slow germination and initial growth rates were associated with resistance. Muthusamy (11) suggested that subapical germination was associated with resistance. In this study,

these traits were not consistently associated with smut resistance in either of two experiments. The frequency of round buds and dorsal or subapical germination was higher in R and MS clones, whereas HS clones showed a strong tendency towards ovate buds and apical germination. However, there was enough variation among clones within the R and MS groups to make these traits unreliable for prediction of resistance or susceptibility. In addition, the types of bud germination, the times (days) required for bud germination, and initial growth rates of R, MS, and HS clones differed significantly between Experiment I and Experiment II, conducted during October and November of 1986.

Table 5. Numbers of smut infections resulting in plants inoculated as ungerminated buds or with primary shoots of increasing length in two sugarcane clones, CP 65-357 and CP 74-383.

Shoot length interval (cm) <sup>1</sup>	No. of buds inoculated <sup>2</sup>		No. of infected plants <sup>3</sup>		Smut infection percentage	
	CP 65-357	CP 74-383	CP 65-357	CP 74-383	CP 65-357	CP 74-383
0	30	32	0(0)	2(0)	0	6
0.1-6	34	42	7(0)	20(0)	21	48
6.1-12	30	36	2(1)	1(0)	7	3
12.1-18	26	40	1(0)	3(0)	4	7
18.1-24	15	20	1(1)	1(0)	7	5

<sup>1</sup> Single-bud cuttings of each clone were inoculated with smut spores as ungerminated (0) or germinated with primary shoot lengths categorized into intervals of 0-6, 6.1-12, 12.1-18, or 18.1-24 cm.

<sup>2</sup> Cuttings were dip-inoculated in a smut spore suspension for 10 minutes and incubated in a germination chamber at 30 C for 18 hours, surfaced sterilized, and planted.

<sup>3</sup> Smut infections were determined by the observation of fungal mycelium in apical meristems of the primary shoots or lateral buds. The number in parentheses indicates the portion of smut-infected plants in which the infection was detected in the secondary shoots but not in the primary shoot.

Previous studies suggested that environmental conditions can affect morphological and growth characteristics (8,11,17). In this study, it appeared that environmental conditions prior to cutting, most likely temperature, affected bud germination times and initial shoot growth rates. Growth rates for many clones were significantly lower for cuttings obtained during November; however, no consistent pattern was evident in the changes in times required for bud germination.

An interaction between growth rate and the length at which developing shoots of a clone become resistant to infection affects the period of time a shoot is susceptible to infection and the chance of coming into contact with smut spores. The results of the experiment to determine the length at which initial shoots of two cultivars, CP 65-357 and CP 74-383, became resistant to infection were very similar to the results of a study conducted with one cultivar by Bock in Kenya (3). In both studies, susceptibility decreased sharply after shoot lengths exceeded 5-6 cm. Infections developed at low frequencies in plants inoculated at shoot lengths ranging from 6-20 cm. No infections developed in plants inoculated at shoot lengths greater than 20 cm in Kenya, but infections did occur at low frequencies in this study in plants of both cultivars inoculated with shoot lengths ranging from 18-24 cm. In one study conducted in India (11), bud sprouting associated with insect damage was correlated with high infection levels in 10 susceptible clones. In another study (12), sprouted buds of one of two cultivars were susceptible to infection. However, no information was given concerning shoot lengths.

A disagreement exists concerning whether or not smut spores can infect ungerminated sugarcane buds on standing cane (3,17). When buds were exposed to smut spores for 18 hours prior to germination, six of 32 (18.8%) of the CP 74-383 plants became infected, whereas none of 30 CP 65-357 plants developed an infection. The results suggest that the level of susceptibility of ungerminated buds to infection varies among clones and may



be related to clone susceptibility. In addition, the frequency of infection in clones susceptible to infection in an ungerminated state appears to be low.

Table 6. Characteristics of infections resulting from wound inoculation with smut spores in resistant (R), moderately susceptible (MS), and highly susceptible (HS) sugarcane clones.

Clone	Smut rating	Total number of stools	No. of smut-free stools	No. of stools with resistance to systemic infection <sup>1</sup>	No. of completely infected stools	Infected stools (%)	Infected stalks (%)	% of stools with resistance to systemic infection	% of infected stalks in stools with resistance to systemic infection <sup>2</sup>
CP 61-37	R	20	20	0	0	0	0	0	0
CP 67-412	R	20	16	4	0	20	6	100	29+18
CP 70-321	R	20	20	0	0	0	0	0	0
CP 72-356	R	17	17	0	0	0	0	0	0
CP 72-370	R	18	18	0	0	0	0	0	0
CP 76-301	R	18	16	2	0	11	2	100	15+11
CP 65-357	MS	17	4	9	4	53	76	69	84+8
CP 74-383	MS	18	4	1	13	78	88	7	92
CP 78-303	MS	20	13	5	2	35	26	71	75+19
CP 78-304	MS	10	0	0	10	100	100	0	0
CP 80-306	HS	18	4	10	4	78	66	71	64+20
CP 80-319	HS	19	1	1	17	95	97	6	93
L 80-38	HS	17	2	9	6	88	70	60	53+24
L 80-45	HS	16	2	0	14	88	81	0	0
L 81-8	HS	17	0	10	7	100	79	59	60+16

<sup>1</sup> Smut infected sugarcane stools showing at least one apparently smut-free stalk.

<sup>2</sup> Value represents a mean except when data recorded only from a single stool.

Previous investigations have suggested that different types of resistance to sugarcane smut can be recognized (7,10). Type I (pre-infectional) and Type II (post-infectional) resistance were terms used in Hawaii to describe different patterns of disease expression in resistant clones (7). Clones with pre-infectional resistance had low incidence of infected plants but high disease intensity in individual plants, whereas clones showing post-infectional resistance had high disease incidence but low intensity. In South Africa (10), pre-infectional resistance was evaluated by measuring the concentration of glycosidic substances in bud scales which inhibited germination of smut spores, and post-infectional resistance was attributed to differences in the colonization rate of hyphae and frequency and type of haustorial development in infected tissues.

The resistance mechanisms which result in differences in disease expression among clones and the times during the infection process when they occur are not clearly understood. As a result, some confusion arises in the use of terms previously used to describe different forms of resistance. Terminology which describes the recognized patterns of disease expression would be resistance to infection and resistance to systemic infection.

Resistance to systemic infection apparently occurs in Louisiana sugarcane clones. Evaluation was difficult in the four resistant clones that did not develop infections. However, this type of resistance was probably active in these highly resistant clones since the barrier represented by the bud scales was pierced during inoculation. The evidence for resistance to systemic infection was strongest for the two resistant clones, CP 67-412 and CP 76-301, in which some plants became infected. In both clones, the proportion of infected stalks within infected stools was low. This resulted in overall low infection levels and resistant reactions for both clones. The absence of infection in CP 70-321 and CP 72-356 in this experiment is in contrast to results of another study (2) in which some smut-infected secondary shoots were observed in plants of both cultivars developing from buds inoculated with the outer bud scales removed.



The infection levels resulting from wound inoculation were high for three of the four MS clones and would have, by other standards, resulted in the assignment to them of a HS smut rating. These results suggest that the expression of resistance in these clones might be partially due to a barrier type of resistance. However, lower levels of resistance to systemic infection were detected in some MS and HS clones. The frequency of stools with resistance to systemic infection was low (6% and 7%) for two clones but higher (59-71%) for the other five clones, and the percentages of apparently smut-free stalks in infected stools ranged from 16-47%.

These results support studies conducted in Barbados (18), Florida (6), Hawaii (7), and South Africa (10) and indicate that mechanisms which limit the development and expression of disease in individual plants contribute to smut resistance.

Resistance to smut is complex and may be expressed in several ways. The relative importance of the different mechanisms of resistance is unclear. Differences may be detected among clones; however, the methods used and the results obtained have varied among studies (2,4,6,7,10,18). The evaluation of stalk infection percentage in clones in annual dip-inoculation tests over more than one season will effectively assess the overall smut resistance of a clone. Thus, the established method is apparently still the best method to reliably evaluate smut resistance in clones in a sugarcane breeding program.

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## THE PRODUCTION OF SEEDLINGS IN THE LOUISIANA, "L", SUGARCANE BREEDING PROGRAM<sup>1</sup>

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### ABSTRACT

Each year the Louisiana, "L", sugarcane breeding program plants approximately 75,000 seedlings at the St. Gabriel Research Station. Over the past three decades, more economical and efficient means of producing and planting these seedlings have evolved. During winter, true sugarcane seed is germinated in flats containing a soil, sand and sphagnum moss mixture. Approximately three weeks after germination, the seedlings are transplanted to individual pots, then grown in the greenhouse until transplanting to the field in April.

Prior to 1960, the seedlings were potted into 7.5 cm clay pots containing sterilized soil. Transplanting of seedlings to the field was by hand. In 1960, clay pots were replaced with 5.7 cm peat pots. Because the peat pots were planted with the seedlings, a tractor drawn mechanical transplanter was used for the first time. In 1978, peat pots were replaced with Jiffy-7 peat pellets. Jiffy-7's did not require filling with sterilized soil; thus time and labor were saved. The Jiffy-7's were transplanted to the field using the same mechanical transplanter as the peat pots.

In 1982, the latest improvements in the production of sugarcane seedlings at LSU were implemented: styrofoam Todd planter flats and two high-speed, mechanical, seedling transplanters. The reusable flats are a handling unit. By planting seedlings of only one cross per flat, the possibility of misidentifying the pedigree of a particular seedling is reduced. Using two high-speed transplanters on a single draw bar, two rows are planted simultaneously, thus decreasing planting time. As a result of these improvements, more seedlings can be grown in less greenhouse space. The total cost and man-hour requirements to complete the seedling production phase of the breeding program has been decreased significantly.

### INTRODUCTION

The primary objective of the Louisiana, "L", sugarcane variety improvement program is to efficiently develop improved sugarcane cultivars for the Louisiana sugarcane industry. Phases of the program include: crossing, seedling production, single stool selection, evaluation in line trials, replicated infield variety testing and replicated outfield variety testing (3).

In January of each year, approximately 150,000 viable seed from a total of approximately 200 biparental crosses are germinated under greenhouse conditions. From these, approximately 75,000 seedlings are planted in the field at the Louisiana Agricultural Experiment Station's St. Gabriel Research Station, St. Gabriel, Louisiana. Over a 13-year selection and testing regimen, it is possible that one or more of these seedlings may become a commercial cultivar.

Over the past three decades, the system of producing and transplanting these seedlings has changed. Today's system is more efficient and cost effective. The purpose of this paper is to describe the changes and improvements that have taken place during this time.

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## DISCUSSION

The process of germinating the true seed or "fuzz," as described by Breaux (3), has remained relatively unchanged over the past three decades. Handling of seedlings after germination through transplanting to the field, however, has undergone major changes.

Prior to 1960, seedlings were potted from germination trays into 7.5cm clay pots which were filled with a sterilized mixture of screened soil, sand and peat moss (6.5:1:3)<sup>2</sup>. After potting, the seedlings were placed on greenhouse benches and grown for 60 to 65 days. Young plants were then transported to the field in April where they were removed from the clay pots and planted by hand. Empty pots were gathered and cleaned for use in subsequent years. From 1960 through 1978, 5.7 cm peat pots replaced the clay pots (1). In April, the plants were removed from the benches, placed in metal trays and transported to the field for planting using a mechanical New Holland transplanter (2).

There were several advantages of peat pots over clay pots. The extra work in gathering and cleaning clay pots for reuse was eliminated since the peat pots were planted along with the seedlings. Handling of the seedlings was easier since peat pots are not as heavy or fragile as clay pots. Peat pots utilized less greenhouse space than clay pots, and the mechanical transplanter could now be used.

From 1978 through 1981, Jiffy-7's<sup>3</sup> were used in the seedling program. The Jiffy-7's were soaked in water until expanded and placed in metal trays. Seedlings were then transplanted into the Jiffy-7's, and taken to greenhouse benches and grown for 60-65 days following a similar routine as had been used with peat pots.

An advantage of using Jiffy-7's was the elimination of screening, mixing and sterilizing soil for filling pots. This resulted in a saving of time and labor during transplanting for greenhouse growth. The Jiffy-7's were lighter and used less greenhouse space than peat pots. The same New Holland mechanical planter was also used with Jiffy-7's when transplanting to field.

In 1981, the utilization of the Speedling system<sup>4</sup> for the greenhouse growing of sugarcane seedlings was investigated. Due to the success of these experiments, the system was incorporated in the new construction of the sugarcane breeding complex at St. Gabriel.

The planting system included model 150 styrofoam Todd planter flats with 128, 3.8 cm square cells filled with Jiffy-mix Plus<sup>5</sup> potting media. With the Speedling system the entire flat is placed on a specially designed bench in the greenhouse which allows air pruning of the roots as the seedlings grow. This causes the seedlings to form vigorous, yet easily removable root balls in individual cells of the flats. The seedlings remain in the flats in the greenhouse for 60-65 days after which time the flats are transported to the field and the seedlings are removed and mechanically transplanted.

The Speedling system has several advantages over the former systems: no soil is screened, mixed and sterilized; the lighter styrofoam flats are easier to handle; decreased chance of accidental mixing of crosses; less labor intensive; less greenhouse space (Table 1); watering and fertilization is automated through the use of the traveling spray boom (Figure 1); and through the use of two Model 6000 high speed mechanical transplanters<sup>6</sup> attached to a single drawbar (Figure 2), planting time in the field is decreased considerably (Table 2).

The amount of greenhouse space required to produce a seedling crop has decreased with each new method introduced. Whereas 183 seedlings per square meter could be grown using clay pots, 538 plants per

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<sup>2</sup>Giamalva, M. 1986. Personal communication.

<sup>3</sup>Manufactured by A/S Jiffy Products Ltd., Norway.

<sup>4</sup>Speedling Incorporated, P. O. Box 238, Sun City, FL 33586.

<sup>5</sup>Jiffy Products of America, 250 Town Road, West Chicago, IL 60185.

<sup>6</sup>Mechanical Transplanter Company, Box 1008B, Holland, MI 49423.



square meter are now produced using the styrofoam planter flats. This has allowed for expansion of the seedling program without greatly increasing resource use.

Table 1. The amount of greenhouse space utilized by each planting system as indicated by the number of plants per square meter of greenhouse area.

Planting system	Number of plants per square meter
Clay pots	183
Peat pots	269
Jiffy 7's	420
Speedling	538



Figure 1. Watering and fertilization of seedlings with automated spray boom.



Figure 2. Transplanting seedlings to the field using two high-speed mechanical transplanters attached to a single drawbar.

Table 2. The rate of transplanting for each system as indicated by the number of plants placed in the field per day and the number of days taken to complete the planting operation.

Planting system	Number transplanted	Number planted per day	Days to complete transplanting
Clay pots	60,000	3,000	20
Peat pots	65,000	7,500	9
Jiffy 7's	65,000	7,500	9
Speedling	75,000	25,000	3

It is important to transplant the seedlings to the field in a relatively short period of time. Transplanting rate has increased significantly over the years. Prior to 1960, approximately 60,000 seedlings were hand-planted at a rate of 3,000 per day. Today, through the use of the two-row Speedling planter, planting rate has been increased to about 25,000 seedlings per day, a more than eight-fold increase.

As a direct result of these improvements, the total cost and man-hour requirements to complete the seedling production phase of the breeding program has been significantly reduced.

NOTE: Mention of a specific vendor does not constitute an endorsement of that vendor to the exclusion of all others that may also be suitable.

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## **ECONOMIES OF SIZE IN THE LOUISIANA SUGARCANE PROCESSING INDUSTRY**

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### **ABSTRACT**

Structural changes in the Louisiana sugarcane processing industry prompted an investigation into the economic efficiencies being experienced as the industry adjust toward fewer and larger firms. Economics of scale estimates were sought as a measure of economic efficiencies. Several methods for estimating economies were discussed, and one was selected for analysis of the industry. Analysis of primary cross-sectional data from 1979 through 1985 using the statistical cost technique indicated that on average the industry is experiencing increasing returns to scale. Implications of the analysis pointed to the industry continuing to adjust toward few large firms.

### **INTRODUCTION**

The sugarcane processing industry in Louisiana has been adjusting toward fewer and larger firms for more than a century. Ever since the industry started the transition from plantation-oriented milling to centralized commercial processing in the 1870's, the number of processors has generally declined, while the average tons of sugarcane processed per mill has generally increased. This latter adjustment has been in response to demands made on the surviving capacity by cane made available from exiting firms, and a general increase in the size of the cane crop. Although firms have grown larger over time, little is known about their relative efficiencies.

While many factors can affect structural changes in an industry, concentration within a food manufacturing industry, such as sugarcane processing, can be attributed in large part to cost economies enjoyed within certain ranges of output. This paper examines the relationship between processing cost and output for the sugarcane processing industry in Louisiana. Specifically, this paper seeks to determine whether the cost economies being experienced in the industry are positive, negative, or constant, and to identify the relative cost of output for various size categories of sugarcane processing firms

This paper proceeds by first describing structural changes within the Louisiana sugar industry over the past two decades. Second, the theoretical basis for the analysis is discussed, and prospects for the future of the Louisiana sugarcane industry are offered. Finally, the empirical results are reported. As fewer firms are available to process Louisiana's sugarcane crop, measures of the industry's economic performance will be of increasing interest to policy makers and industry participants.

#### Structural change in the Louisiana sugarcane processing industry

Changes taking place in the Louisiana sugarcane processing industry over the past several decades are reviewed by discussing four elements of market structure: 1) the number of raw sugar factories, 2) the grinding capacity per mill per day (size), 3) the average number of tons of sugarcane ground per mill per season, and 4) the average total operating cost for sugarcane processing. The number of factories operating in the state remained fairly stable from 1959 through 1973 (Figure 1). However, from 1973 through 1982 the number of mills dropped approximately fifty percent, averaging a decline of slightly more than two mills per year. Since 1982 the number has remained unchanged for an unprecedented six consecutive years.

The average per mill, per day, capacity in tons of cane ground has increased steadily from 1967 through 1985 (Figure 2). The average annual increase for the period was approximately 9.5 percent per year, and approximately 150 percent over the period.



The average tons of sugarcane processed per mill per season tended to increase over the period under examination (Figure 3). The percentage change between years is somewhat erratic, due to changes in the number of mills operating in the state in a given season, and the total tons of cane harvested in a given season. This latter variable tends to vary widely relative to the number of factories.

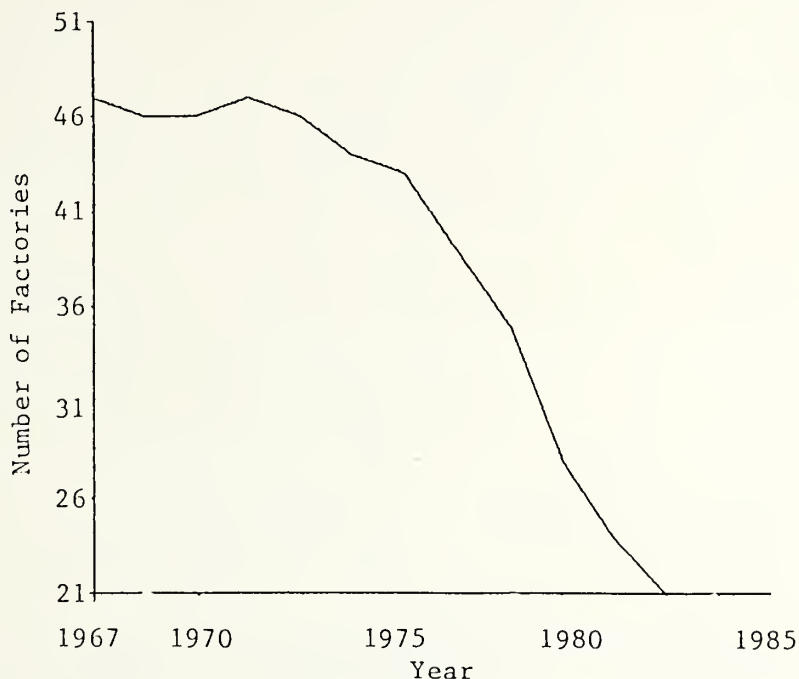


Figure 1. Number of sugarcane processing factories, Louisiana, 1967-85

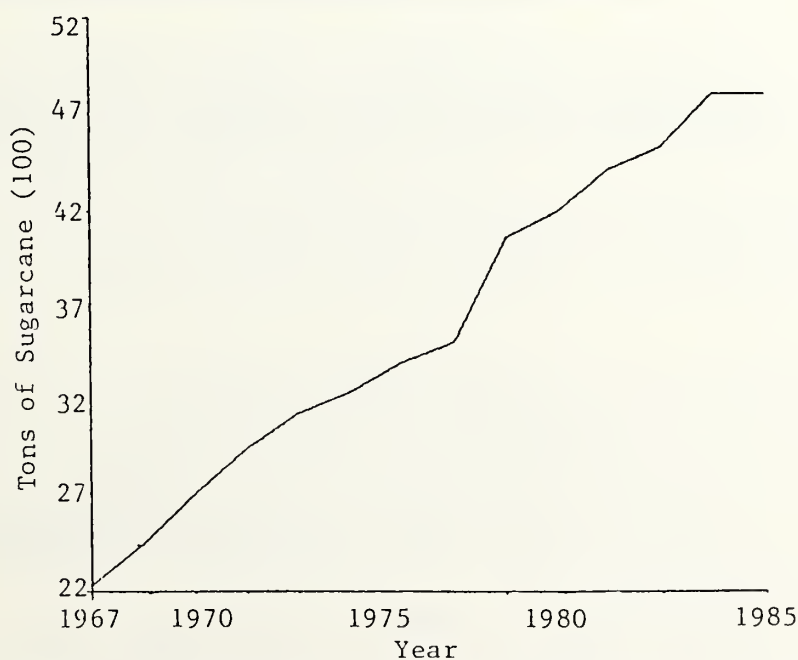


Figure 2. Average tons of sugarcane ground per day per mill, Louisiana, 1967-85.

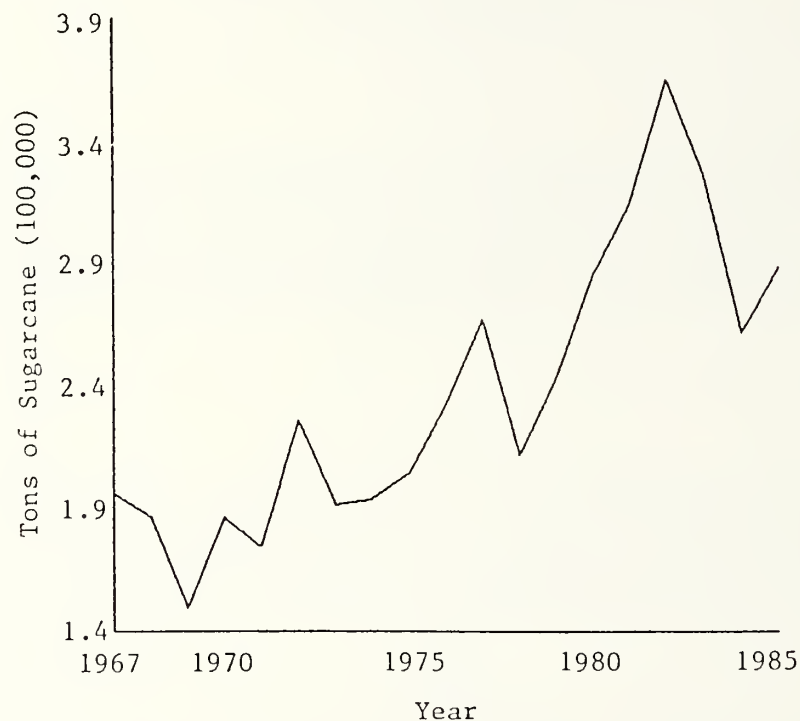


Figure 3. Average tons of sugarcane processed per mill per season, Louisiana, 1967-85.

In an effort to understand how processor operating cost behaved over time, two measures of cost were considered. The first of these, total cost, tended upward over time, but displayed dramatic up and down movements during certain periods, due in large part to increases and decreases in the cost of sugarcane (1). The cost of sugarcane is tied directly to the price received for raw sugar. In Louisiana, sugarcane growers typically receive 61 percent of the value of the raw sugar derived from the cane the grower ships to the processor. This arrangement accounts for the dramatic increase in total cost in 1973/74, when raw sugar prices reached historic high levels. Similarly, operating costs fell dramatically in 1975, when raw sugar prices returned to more normal levels.

A better understanding of the changes in operating costs as they relate to operating profits may be had by the second measure, total cost less the cost of cane, deflated to account for increases due to inflation (Figure 4). This latter measure indicates a sharp rise in cost from 1969 through 1975, and a general decrease in cost during subsequent years. The exception in this latter period is a sharp rise and fall in 1980 and 1981, respectively.

The general conclusions from the observations noted above are that the industry is adjusting toward fewer firms, and these firms are increasing their capacities. Further, the surviving firms are in fact processing increasing amounts of sugarcane, yet not always at decreasing cost per unit. This cost-output relationship is examined in the balance of this paper.

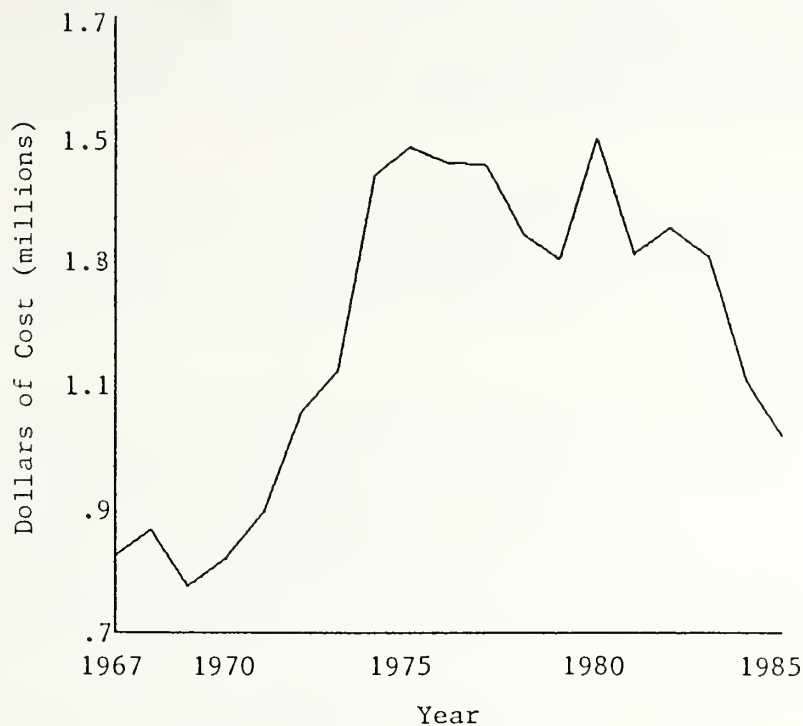


Figure 4. Average total sugarcane processing cost less cost of sugarcane, deflated for inflation, Louisiana, 1967-85.

#### The relationships between firm costs and output: theory and method

Microeconomic cost theory provides a basis for identifying the relationships existing between the cost and output of a firm. Of particular interest to an analysis of the cost economies existing in an industry is the set of theory related to average cost, or cost per unit of output. In cursory terms, the slope of an average cost curve yields the response of cost to changes in output. Cost theory is generally framed in two time horizons - short run cost theory and long run cost theory.

In the long run, all inputs are assumed to be proportionately and optimally adjustable for various levels of output. Firms are assumed to be able to select among various optimum firm sizes in terms of output. As firm size (output) increases, the firm can experience three possible returns to scales. The long run is applicable to time series analyses and situations which permit the rather unrealistic long run assumptions. For this particular analysis, neither is the case.

In the short run, the firm operates under some set of fixed inputs, hence firm size is fixed, and output is limited to a certain range of output. However, as in the case of the long run horizon, three possible cost economies may exist over the range of output - economies of size, diseconomies of size, and constant returns to size, which translate to decreasing cost per unit, increasing cost per unit, and constant cost per unit, respectively. The short run horizon applies to cross-sectional data like those used in this analysis, and can accommodate the assumptions required in this type analysis.

Short run cost theory proceeds from the production function to the cost function, the elasticity of which gives the response of cost to changes in output (3). With some enabling assumptions, the production function can be stated as a schedule of the maximum amount of output that can be produced from a specified set of variable and fixed inputs, given a state of technology. The general physical characteristics of a production

function are held by the Law of Diminishing Returns. The law insists that, given a set of fixed inputs, and successive equal increment of a variable input, total physical product, or total output will first increase at an increasing rate then increase at a decreasing rate to a maximum at which point the total output decreases. A production function can demonstrate all three of these relational forms. The sources of these relationships are generally said to result from the specialization and division of labor and technological factors. Neither source is easily or clearly identifiable without rigorous examination of the production process. Consequently, this analysis does not attempt to identify the sources of the economies estimated for the Louisiana sugarcane processing industry.

Production (processing) cost is a monetarized expression of the explicit and/or implicit inputs in the production process. Hence, a cost function by definition embodies a measure of the physical as well as the economic relationships between the fixed and variable inputs and output of the production function. Because of this definitional linkage between the production and cost functions, by the Law of Diminishing Returns are likewise imposed on the cost function. Furthermore, these relational forms dictate the cost economies experienced at various levels of output.

Alternative methods exist for measuring scale and/or size economies (4, 5). Engineering studies are based on technological or physical relationships between the capacity of a particular machine and its output. To the extent this approach applies to a single machine, it may lack broader economic implications.

The survivor test holds that competition within a market will drive out inefficient firms in the long run (4). Empirical estimation of economies of scale by this technique is performed by classifying firms within a market by size, and measuring the change in relative market share of these firms or their categories. The implications are that more efficient firms will increase market share. The limits of this approach are recognized when the nature of competition is known, and the resulting trade-offs between private efficiency and public efficiency are explored (6).

The statistical technique relates cost to output data to make inferences about scale economies (3). A major problem in applying this method is acquiring data, particularly from manufacturing firms where information is often regarded as too sensitive to share with public researchers. Because this caution occurred in only limited instances within the Louisiana sugarcane processing industry, the statistical technique could be employed to determine the existence of economies of scale for this industry.

A simple example of a total cost curve that satisfied the inverse curvature postulated in the production function is the cubic cost curve (2):

$$C = \beta_0 + \beta_1 Y + \beta_2 Y^2 + \beta_3 Y^3$$

where  $\beta_0$ ,  $\beta_1$ ,  $\beta_2$  and  $\beta_3$  are given parameters. The familiar average cost and marginal cost associated with the cubic cost curve is written as:

$$Ac = \frac{\beta_0}{Y} + \beta_1 + \beta_2 Y + \beta_3 Y^2$$

$$Mc = \beta_1 + 2\beta_2 Y + 3\beta_3 Y^2$$

A convenient measure of economies of scale is given by the elasticity of cost,  $\gamma$ , the elasticity of the cost curve with respect to output, written as:

$$\gamma = (Y) = \frac{Y}{C(Y)} \frac{C'(Y)}{C(Y)}$$



where factor prices are assumed given.  $\gamma$  can be interpreted as:

$$\gamma = \begin{matrix} \text{economies of scale} & < \\ \text{constant returns to scale if} & = 1 \\ \text{diseconomies of scales} & > \end{matrix}$$

Using the cubic cost function and the elasticity of cost presented above, economies of scale can be measured for the Louisiana sugar mills.

### EMPIRICAL RESULTS

Ordinary least squares regression was used to estimate the cost-output relationship within sugar processing industry in Louisiana. The functional form used to estimate the cost-output relationship is:

$$\text{Cost} = b_0 + b_1 \text{Gnd} + b_2 \text{Gnd}^2 + b_3 \text{Gnd}^3$$

where

Cost = Total annual cost of processing sugar per plant.

Gnd = Total raw cane ground as a measure of output.

$\text{Gnd}^2$  = Total raw cane ground squared.

$\text{Gnd}^3$  = Total raw cane ground cubed.

Operating cost and return data, and selected physical data, representing fifteen Louisiana sugarcane processors for grinding seasons 1979 through 1985, were collected via personal interviews during the summer of 1986. These data were obtained from annual audited statements.

Table 1. Estimated cubic total cost function coefficients for Louisiana sugar mills for years 1979-85 and the average of years 1979-1985.<sup>1</sup>

Year	Constant Term $B_0$	Gnd $B_1$	$\text{Gnd}^2$ $B_2$	$\text{Gnd}^3$ $B_3$	$R^2$	F Ratio
1979	24431592.83	-335.7594 (3.068)	.0016 (3.184)	-2.2747E-09 (3.184)	.800	14.698
1980	18430069.26	-204.5996 (2.609)	8.3366E-04 (2.915)	-1.0117E-10 (3.065)	.762	11.712
1981	11086815.52	-81.6395 (0.670)	2.70062E-04 (0.737)	-2.5757E-10 (0.732)	.347	1.948
1982	6819642.20	-33.5309 (0.417)	1.14184E-04 (0.508)	-1.0076E-10 (0.502)	.479	3.365
1983	30818825.29	-284.5331 (2.193)	9.53420E-04 (2.289)	-9.9269E-10 (2.300)	.669	7.408
1984	11930373.88	-126.5464 (1.081)	5.63153E-04 (1.309)	-7.1874E-10 (1.448)	.548	4.442
1985	68379894.35	-762.05 (2.688)	0.0029 (2.793)	-3.5418E-09 (2.854)	.692	8.247
Average 1979-85	43827536.60	-456.6476 (2.725)	1.6826 (2.884)	-0.0019 (2.942)	.735	10.161

<sup>1</sup> Number in parenthesis are t-statistics.

The model was initially run using cross sectional data for each year. This approach yielded disappointing results, which were contrary to theoretical expectations (Table 1). The results yielded incorrect signs, yet significant coefficients, and reasonably high coefficients of variation. Efforts were made to improve the results of the remaining years by using log models, a quadratic functional form, changing dependent variables, and using other measures of firm output. These attempts failed to improve earlier results. Finally, running the model using a linear functional form yielded satisfactory results (Table 2).

Table 2. Estimated linear total cost function coefficients for Louisiana sugar mills for years 1979-85 and the average of years 1979-1985.<sup>1</sup>

Year	Constant Term B <sub>0</sub>	Gnd B <sub>1</sub>	R <sup>2</sup>	F Ratio
1979	440332.60	11.0571 (2.4202)	.6162	20.872
1980	1583513.48	9.0078 (2.6222)	.4758	11.801
1981	1720862.68	7.9549 (3.2555)	.3147	5.971
1982	2192967.22	7.4429 (2.2087)	.4662	11.355
1983	1810770.14	9.4823 (2.5806)	.5095	13.501
1984	2204478.49	8.2751 (3.5280)	.2974	5.502
1985	1418870.34	9.4977 (3.0300)	.4305	9.825
Average 1979-85	1086228.50	7.8663 (2.2143)	.5133	13.712

<sup>1</sup> Number in parenthesis are t-statistics.

It was concluded that the data represented output ranges which were best described by a linear relationship between cost and output. Furthermore, it was suspected that averaging over the seven year period, would provide a more representative performance of the firm, because unique annual factors, beyond the control of management, were spread evenly across the seven years under examination. Therefore, an average of the output (Gnd) and total cost (Cost), deflated for inflation, for each firm over the seven year period was tested, and resulted in the expected statistical results. The results of this later cross-sectional model are provided below:

$$\text{Cost} = 1,086,228.5 + 7.866(\text{Gnd})$$

(2.124)

$$R^2 = .51$$

$$F \text{ Ratio } 13.712$$

Overall this model performed well in explaining the cost-output relationship in the Louisiana sugarcane processing industry during the period of study. The signs are as expected, and the R<sup>2</sup> suggests this model fits

the data well enough to allow conclusions about cost economies in the industry. Moreover, coefficients for years other than 1981 and 1984 were significant at the 1% level. Coefficients for the exception years were significant at the 5% level. This model was chosen to compute the elasticity of cost, the chosen measure of economies of scale. Dividing average output by the average costs and multiplying by the coefficient B (Gnd) an cost elasticity of .6864 was obtained as shown below:

$$\gamma = \frac{302229}{3463648} \times 7.866 = .6864$$

A coefficient of less than 1.0 suggests that on average the Louisiana sugarcane processing industry experienced increasing returns to scale during the period under study. If Louisiana sugarcane processors increase their average output, operating costs per unit should be expected to decrease.

### CONCLUSIONS

As an industry becomes more concentrated, it becomes appropriate to examine the efficiency of firms operating in that industry. Significant structural changes have occurred in the Louisiana sugarcane processing industry. Over time, the industry has adjusted toward fewer and larger processors. To understand the economic implications of these structural changes, this study investigated size economies within the Louisiana sugarcane processing industry as a measure of economic efficiency. The empirical results of this analysis suggest that on average firms in the industry operated at increasing returns from 1979 through 1985. This suggest that average firm efficiency has improved as average firm size increased during this period.

The results of this study have implications for the future direction of the Louisiana sugar industry. They suggest further adjustments toward fewer and larger sugarcane processing factories are possible. As current and future technologies allow for increasing economic returns to factory size, firms can be expected to increase output in an attempt to reduce per unit cost and maintain or improve their competitive position. Firms unable to take advantage of greater outputs may find themselves in a weakening position. The process of adjustment and the rate at which it proceeds will be impacted in large part by the domestic demand for refined sugar and in the price received for raw sugar. A decrease in either should act to drive the industry toward further concentration.

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## A METHOD FOR DETERMINING SPORE PRODUCTION OF SUGARCANE RUST, (*Puccinia melanocephala*).

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### ABSTRACT

A method was developed for measuring spore production of sugarcane rust (caused by *Puccinia melanocephala* H. Syd. and P. Syd.) using a Coulter Counter<sup>1</sup>. Spore counts of suspensions of spores at concentrations higher than 5000 spores/ml did not differ significantly from counts made using a hemacytometer slide. The mean number of spores per ml and standard error using the Coulter Counter were 1247 and 102, and 1630 and 847 using the hemacytometer in a suspension containing approximately 1250 spores per ml. The time required to make determinations using the Coulter Counter was 33% less than the time required to make counts under the microscope. Leaves were collected from the field, sectioned, and spores were collected after an 18 hour incubation period. Accuracy of estimates of rust intensity were improved by sampling more than one field of the same clone and several rows in each field. The number of samples taken per row and number of readings taken per sample had little effect on accuracy. Large field areas may be evaluated efficiently with a relatively small number of samples. Mean rust spore production per unit leaf area for a given clone can be determined to a specified level of precision.

### INTRODUCTION

Rust, caused by *Puccinia melanocephala* H. Syd. & P. Syd., is now an important disease of sugarcane. The disease was first discovered in Florida in 1979 by Dean et al. (2). Since that time numerous changes in host-cultivar resistance have been observed (1). A quantitative method for measuring disease severity is needed to evaluate sugarcane rust resistance both in agronomically acceptable clones intended for commercial production and in breeding lines to be used to develop cultivars with stable resistance to rust.

The most common method used in sugarcane to evaluate rust disease levels in Florida is a visual rating scale from 0-4 (8). This method is quite useful for rapidly screening large numbers of progeny and clones in a breeding and selection program. Methods for visually estimating percentage leaf area infected have been used to measure rust levels in both cereals and sugarcane (4,6). Neither method is quantitative nor sensitive enough to detect slight differences in disease intensity.

There is a positive correlation between the number of spores produced on infected wheat leaves and the progress of a rust epidemic (7). Methods to count the number of spores produced per unit area of leaf tissue have been employed in the rust-small grain pathosystems to evaluate varietal susceptibility to rust (3,4). These methods include counting collected spores produced per unit area of leaf tissue directly under the microscope using a hemacytometer (9) and weighing collected spores on an analytical balance (3). A Coulter Counter Model B was used in 1972 to assess intensity of yellow rust on European wheat cultivars (5). Quantitative differences in disease intensity were detected, but the method required extensive sample preparation.

This study presents an improved method using a Coulter Counter Model ZM (Coulter Electronics Limited, Northwell Drive, Luton, Beds., LU3 3RH England) to quantify the number of sugarcane rust spores

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<sup>1</sup>Trade names are used in this publication solely for the purpose of providing specific information. Mention of a trade name does not constitute a guarantee or warranty of the product by USDA or any endorsement by the Department over other products not mentioned.



produced per unit area of leaf. The Coulter Counter Model ZM is designed to count particles of a known size suspended in an electrolytic medium containing a heterogeneous particle size distribution. The principle is based on the change in resistance of current as a particle passes through an aperture. This change in resistance is a function of the volume of particles. Calibration of the device with particles of known size allows the desired upper and lower particle size limits to be set.

The objectives of these experiments were to: 1) develop a method to remove all mature spores from leaves or leaf sections; 2) compare counts made with the Coulter Counter with the counts made with a Spenser Hemacytometer slide; 3) develop sampling methods for sugarcane leaves in the field to determine the necessary numbers of blocks or locations, rows, leaves and aliquots of spore suspension required to make efficient, accurate estimates of spore production per unit leaf area.

## MATERIALS and METHODS

A Coulter Counter Model ZM calibrated for a 100 micron aperture tube was set to count particles within a range of  $20.11\mu$  -  $40.22\mu$ . The spores collected typically ranged from  $22-25\mu \times 33-36\mu$  based on measurements made under a microscope. Though teliospores are known to occur in Florida none were observed on the samples collected in these experiments. The spores collected were observed to be urediospores. Spore counts made with the Coulter Counter were compared to counts made under the microscope with a Spenser Hemacytometer. The design of the slide and its calibration were described by Tuite (9).

Spores were collected from heavily infected-leaves of sugarcane cultivar CP 78-1247. Spores were collected by washing leaf sections taken from the top visible dewlap leaf in an ultrasonic bath (Mettler Electronics, Pasadena, Calif.). This concentrated spore suspension was diluted with distilled water to prepare three 250 ml suspensions containing approximately  $1 \times 10^5$  spores/ml. The concentration of the three spore suspensions were estimated to be  $17.9 \times 10^4$ ,  $9.7 \times 10^4$ , and  $5.8 \times 10^4$ , respectively. The suspensions were prepared to compare spore counts from serial dilutions between the Coulter Counter and the hemacytometer. The dilution was distributed as 1:99, 1:9, 1:1, and 1:0 parts original stock suspension to parts distilled water. Each dilution was prepared for 100 ml final volume. Each dilution was stirred constantly while nine, 5 ml aliquots were drawn and placed in 15 ml of Isoton II electrolyte. Three spore counts were made on each of the nine samples from the three stock suspensions using both methods. A second dilution series was conducted using a single stock suspension estimated to contain 1000 - 1500 spores/ml. The spores were collected in electrolyte and the dilution series prepared and counted as described above.

A second experiment was conducted to devise a method to collect spores from leaves on cane growing in the field. Entire leaves were collected from each of two replicates of a field trial containing seven clones. The test was planted on August 26, 1987. Six rows 9-m-long and 1.5 m apart were planted in each plot in a randomized complete block design.

The top visible dewlap leaf was selected to evaluate rust intensity throughout this experiment. A total of 40 leaves were collected from each plot by removing the entire leaf blade from the plant. Two samples of five leaves were taken randomly from each of the four central rows in each plot from tillers of approximately the same height on March 15, 1988. Leaves collected from each row were bundled in groups held by a rubber band at the base of the leaf and placed in a large plastic bag to prevent desiccation during transport.

Early investigations revealed that large amounts of debris adhered to field-collected leaves. This debris interfered with determinations made using the Coulter Counter. Spores adhering to the leaf and debris were removed by washing the leaf with distilled water delivered by a pressure sprayer operated at 60 psi. This was enough pressure to remove debris and moisten the leaf surface without fraying the leaves. The moist leaves were then placed basal end down in a bucket containing 4" of water and covered with a loose fitting plastic bag, then placed in a dark room at  $25^\circ\text{C}$  for 18 hours. One bucket contained four bundles of ten leaves representing each of the four rows sampled in each plot. The leaves were removed from incubation and samples prepared to count spores produced over the 18-hour-period.

Leaves were sectioned by measuring 30 cm from the tip of the leaf and taking ten,  $1.25 \times 2.5$  cm rectangular sections at 5-cm-intervals in a basipetal direction on alternating sides of the mid-vein. The sections

were cut with a patch budder designed for budding pecan trees in nurseries. The cutting tool minimized leaf handling and provided a quick way to obtain sections of uniform size. The sections represented approximately 10 to 15% of the total surface area of each leaf.

Sections from the five leaves were placed in a 45 ml test tube containing 2 ml of Isoton II electrolyte solution. The tube was closed with a screw cap to prevent desiccation while preparing samples. An additional 28 ml of electrolyte was added to each test tube to collect spores from the leaf sections. This was sufficient to cover all of the tissue in the container. The test tubes containing the leaf sections in electrolyte were placed in a low frequency, low intensity ultrasonic cleaning bath for 20 minutes. Each tube was shaken vigorously to resuspend any spores that may have settled to the bottom of the tube before drawing the first aliquot. Three, 5 ml aliquots were drawn from each test tube and each was placed in a cuvette containing 15 ml of electrolyte. Three spore counts were made on each of the prepared samples using the Coulter Counter. The estimated spore production per unit area of leaf surface based on the average of three determinations for the 18 hour incubation period was analyzed statistically using the model:

$$Y_{ijklm} = \mu + \beta_i + \delta_j + (\beta\delta)_{ij} + p_{k(ij)} + \sigma_{l(kij)} + \alpha_{m(lkij)}$$

Where:  $Y_{ijklm}$  = the reading from the  $m^{\text{th}}$  aliquot sample within the  $l^{\text{th}}$  sample within the  $k^{\text{th}}$  row within the  $j^{\text{th}}$  clone of the  $i^{\text{th}}$  block.

$\mu$  = overall mean

$\beta_i$  =  $i^{\text{th}}$  block

$\delta_j$  =  $j^{\text{th}}$  clone

$p_{k(ij)}$  =  $k^{\text{th}}$  row within the  $j^{\text{th}}$  clone and the  $i^{\text{th}}$  block

$\sigma_{l(kij)}$  =  $l^{\text{th}}$  5-leaf sample within the  $k^{\text{th}}$  row

$\alpha_{m(lkij)}$  =  $m^{\text{th}}$  aliquot within the  $l^{\text{th}}$  sample

The calculated variance components were used to calculate the number of blocks or locations, rows, five-leaf samples and aliquots required to estimate the mean number of spores produced per unit area of leaf tissue on a given clone at a specified level of precision.

## RESULTS and DISCUSSION

Spore counts made with the Coulter Counter Model ZM were compared to counts using a hemacytometer to test the accuracy of an unknown method against an accepted method of counting rust spores. The recommended usage of the hemacytometer requires 200 to 250 spores in one microscopic field of view to obtain an estimate within 10 - 15% of the true mean concentration of the stock suspension (10). Counts of this magnitude estimate concentrations on the order of  $5 \times 10^5$  spores/ml of suspension. The same order of concentration of cells is recommended to obtain the most accurate results with the Coulter Counter. The first dilution series was designed to fit within the range of the highest degree of accuracy of both methods to compare their relative accuracies. Data presented in Table 1 show that the estimate of the spore concentration in the three-stock suspensions averages two times the expected result using the Coulter Counter and four times the expected result using the hemacytometer at the 1:99 concentration. The estimated mean number of spores in the stock suspensions at the 1:9, 1:1 and 1:0 concentrations were not significantly different within each of the three suspensions regardless of the method, but the standard errors using the hemacytometer at the 1:9 and 1:1 concentrations were more than twice that of the Coulter Counter estimates. The most consistent results were obtained at the 1:1 and 1:0 concentrations using the Coulter Counter with the standard error averaging less than 2% of the estimated mean (Table 1).



The spore concentration in the 1:99 dilution from each suspension was less than 1000 spores per ml. Data from other experiments indicate the number of rust spores on leaves bearing fruiting pustules range from 100 - 2500 spores/cm. This would yield approximately 300 - 6000 spores/ml using our current sample preparation methods (unpublished data). A new suspension containing approximately 1250 spores/ml was made to determine whether concentrations in the range found on collected leaves could be accurately determined. The standard error of the 1:0 dilution was less than 10% of the estimated concentration using the Coulter Counter and more than 50% of the estimate using the hemacytometer slide (Table 2). The standard error at the 1:9 dilution using the Coulter Counter averaged near 10% of the estimate while the standard error using the hemacytometer averaged more than 40%. There was concern based on these data that neither counting method was sufficiently accurate to estimate the number of spores contained in dilute spore suspensions.

The estimate of the mean number of spores contained in the 1250 spores/ml stock suspension obtained with the Coulter Counter suggests that preparation of the dilution series was the largest contributor to error within the original 3 stock suspensions. The estimated mean of the 1250 spores/ml stock suspension calculated from the 1:99 dilution counts was more than 50 times greater than the expected mean with the hemacytometer and more than four times the expected mean with the Coulter Counter. The standard error was 27217 with the hemacytometer and 1599 using the Coulter Counter at the 1:99 dilution.

Table 1. Estimated mean number and standard error (SE) of rust spores per ml of sample prepared from three spore suspensions.

Expected Conc. <sup>1</sup>		Suspension 1 17.9x10 <sup>4</sup>				Suspension 2 9.7x10 <sup>4</sup>				Suspension 3 5.8x10 <sup>4</sup>			
Method		Counter		Slide		Counter		Slide		Counter		Slide	
Spore Suspension Dilution <sup>3</sup>	Sample count <sup>2</sup>	Suspension estimate	Sample count	Suspension estimate	Sample count	Suspension estimate	Sample count	Suspension estimate	Sample count	Suspension estimate	Sample count	Suspension estimate	Sample count
-----Spores/ml-----													
1:99	631	252400	2000	800000	376	150400	963	385200	603	241200	296	118400	
1:9	3751	150040	4519	180760	1307	52280	3852	154080	1344	53760	370	14800	
1:1	20646	165168	29333	234664	13505	108040	11111	88888	10452	83616	889	7112	
1:0	43515	174060	46370	185480	26616	106464	19703	78816	25710	100680	21407	85628	
-----Standard Error of Estimates-----													
1:99	47.5	19000	343	137200	16.4	6544	178.3	71320	30.6	12240	80.4	32160	
1:9	72.9	2916	363	14520	35.5	1420	574.6	22984	40.2	1608	87.9	3516	
1:1	254.8	2118	1299	10392	252.5	2020	670.4	5363	183.9	1471.2	142.3	1138.4	
1:0	468.5	1874	1709	6836	384.5	1538	942.2	3769	317.6	1270.4	1098.7	4394.8	

<sup>1</sup> Expected concentration was calculated from the means of the estimated concentration of spores per ml in the parent suspensions at the 1:9, 1:1, 1:0 dilutions using both methods. The values obtained at each of these dilutions were not significantly different within each suspension.

<sup>2</sup> Sample spores per ml means and standard errors were calculated from three spore counts per sample on each of nine samples.

<sup>3</sup> Parts of stock suspension to distilled water. Five-ml samples from each dilution were placed in 15 mls of electrolyte, therefore the counts presented are multiplied by a factor of 4 times the dilution factor to obtain spores per ml of each stock suspension.

Results obtained at the 1:1 and 1:0 concentrations with the Coulter Counter were similar, the standard error averaging less than 10% of the starting concentration (Table 2). This level of accuracy was not expected since this implies that suspensions containing as few as 500 spores/ml, possibly, could be counted to within 10 - 15% of the true mean population. This degree of accuracy has not been reported with the hemacytometer. The estimated number of spores in the 1250 spores/ml suspension at the 1:0 concentration with the hemacytometer was close to the expected result, but the standard error was more than 50% of the estimated mean.

Table 2. Estimated mean number and standard error (SE) of rust spores per ml of sample prepared from one stock suspension containing approximately 1250 spores per ml.

Concentration <sup>1</sup>	Spores/ml of prepared sample		Spores/ml adjusted to stock suspension	
	Mean	SE	Mean	SE
<u>Coulter counter</u>				
1:99	69.6	15.9	6,963.0	1,599.0
1:9	235.6	23.9	2,356.0	239.3
1:1	604.4	67.4	1,208.9	134.7
1:0	1,237.4	101.7	1,247.4	101.7
<u>Hemocytometer</u>				
1:99	888.9	272.2	88,889.0	27,216.6
1:9	740.7	303.2	7,407.0	3,031.6
1:1	2,148.0	575.0	4,296.3	1,149.9
1:0	1,629.6	847.0	1,629.6	847.0

<sup>1</sup> Concentration in parts of stock suspension to Isoton II electrolyte.

Data presented here for counting dilute suspensions of rust spores are in agreement with similar data presented on bloodwork by the manufacturer. The most important difference between counting blood components and spores produced by fungal pathogens of plants is the fact that blood is essentially sterile and contains no foreign particles. Furthermore, blood components are suspended in a water soluble medium. Spores of many species of fungi, including *P. melanocephala*, are strongly hydrophobic and are extremely difficult to suspend uniformly in water without adding surfactants. The spores tend to adhere to the leaf after release from the pustule and spores being released from the pustules tend to clump, particularly under humid field conditions. These characteristics make working with sugarcane rust more difficult than rusts of cereals which produce large numbers of dry spores readily collected by tapping the leaf over a vessel. We were aware at the outset of these experiments that this might be an important barrier to overcome.

Extraneous spores and leaf debris must be minimized to obtain accurate counts with the Coulter Counter. Several cleaning methods were attempted. The most reasonable method appeared to be washing the leaves with a pressure sprayer using a small amount of water. Leaves had to be incubated for a period of time for fresh spores to be produced after washing. A test was designed to determine the feasibility of washing with the pressure sprayer and to evaluate incubation periods and conditions to optimize spore production and enumeration. Spore counts from washed leaves were approximately 10% of counts from unwashed leaves when leaves were collected from the field and prepared immediately for counting. Other leaves were held in covered buckets for 18 and 36 hours. Spore production was measurable after 18 hours and differences in rust intensity could be detected. Visual observations of washed leaves at 24 hours indicated that many spores had germinated, and mycelia from rust and secondary fungi had begun to cover the leaves. Samples prepared from leaves held for 36 hours after washing were difficult to analyze because of mycelial growth present, and the resulting counts were highly variable.

A procedure to collect and handle leaves from which spore production was to be measured was developed to minimize sample variation. After observing a wide range of rust infection, we chose the top visible dewlap leaf to best represent rust spore production on the majority of clones. Initial infection of sugarcane leaves primarily occurs while leaves are emerging from the whorl. The disease on the top visible dewlap leaf has typically completed its primary infection cycle, pustules are reaching their peak spore production potential and



pustules formed from secondary infections are generally absent. Older leaves are often necrotic and infected with secondary pathogenic and saprophytic fungi.

The leaf sectioning procedure evolved after attempting a variety of methods. Initially, leaves were cut into sections 5-cm-long beginning 20 cm back from the leaf tip. It was noted that the number of pustules occurring on the leaf decreased basipetally, but no numerical relationship was derived. We decided that three, 5-cm sections representing 15 - 20% of the total leaf surface area provided an adequate sample. Sectioning the leaves in this manner was time consuming since the area of each section had to be measured. The patch budder, used to obtain sections of uniform size, greatly decreased the time required to cut the leaf sections. Single-leaf samples were used initially; 10 - 30, single-leaf samples were collected from plots. The coefficient variation using single-leaf samples was greater than 50%, too high to obtain acceptable accuracy in results. Combining sections from five leaves eliminated this wide degree of variation encountered with single-leaf samples.

The number of five-leaf samples required to detect differences in rust spore production among clones needed to be determined before implementing this counting technique to evaluate rust intensities in experiments. The expected mean squares were used to calculate the variance components listed in Table 3 for locations or blocks, rows, five-leaf samples, and aliquots from each sample. The variance components were used to determine the numbers of each sampling unit required for a desired level of accuracy. A coefficient of variation (CV) of 20% was accepted as a suitable threshold for accuracy. The overall mean square root of the number of spores produced per square cm of leaf was 14.25 and the maximum acceptable value of the standard error was 2.85 for a CV of 20%. The corresponding variance was 8.12.

Table 3. Analysis of variance of the square root of spores per square centimeter of abaxial leaf surface area.

Source	Degrees of freedom	Mean square	Variance components
Clones	6	4,458	
Blocks	1	600	1.820
Clones x blocks	6	295	9.050
Rows (clones x blocks)	42	78	11.960
5-leaf samples (r x b x c)	56	6	1.178
Aliquots (s x r x b x c)	224	3	2.906
Total	335	Grand mean =	14.250

Values of 1 and 5 were used for the levels of the sampling variables in Table 4 to illustrate effects of high and low levels of each sampling variable combination on the experimental CV. The table was constructed as a guide for designing experiments to record rust disease progress on clones representing a wide range of rust intensity.

Increasing the number of rows sampled in a large planting from 1 - 5 decreases the CV by 10% when only one field is sampled. Increase in the number of sampled fields from 1 - 5 decreases the CV by 12 to 20% (Table 4). The number of five-leaf samples and aliquots prepared have little effect on the reduction of the CV. An estimate of rust intensity over a larger area could be obtained by sampling one row in five or more fields. Fields can be sampled randomly to obtain disease progress curves for different clones over time to study many aspects of the pathogen and the disease.

Developing a technique to quantitatively measure sugarcane rust intensity has become an important need with the increased presence of the disease in the Everglades Agricultural Area since 1979. The absence of freezing temperatures in the winters of 1986-1987 and 1987-1988 may have lead to the recurrence of epiphytotics. Several edaphic factors have been observed to influence disease intensity and clonal reactions to the disease vary over time (R. Raid, personal communication). There is a consensus that rust races are involved in the south Florida area epidemics, but the extent is entirely conjectural.

Table 4. Estimated coefficient of variation (CV) with changing numbers of sampling variables.

Blocks	No. of rows	5-leaf samples	No. of aliquots	CV
1	1	1	1	36.41
1	1	1	1	34.80
1	1	5	5	34.12
1	1	5	5	33.79
1	5	1	1	26.33
1	5	1	1	25.89
1	5	5	5	25.71
1	5	5	5	25.62
5	1	1	1	16.28
5	1	1	1	15.56
5	1	5	5	15.26
5	1	5	5	15.11
5	5	1	1	11.78
5	5	1	1	11.58
5	5	5	5	11.50
5	5	5	5	11.46

We hope that the reported method of evaluating spore production of sugarcane rust will aid investigators in examining all aspects of this disease that is becoming more of a concern to Florida sugarcane growers.

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## CROP-HERBICIDE MANAGEMENT OPTIONS FOR JOHNSONGRASS CONTROL IN FALLOWED SUGARCANE FIELDS<sup>1</sup>

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### ABSTRACT

Three crop-herbicide management options were imposed on fallowed sugarcane fields in 1981, 1982 and 1984. Crop options included fallow only, wheat + fallow, and fallow + soybeans. Within each option, three levels of johnsongrass control were imposed by the use of plowing or metribuzin at 0.4 kg ai/ha (low/none), trifluralin + metribuzin at 1.1 + 0.4 kg/ha (medium), and trifluralin + metribuzin at 2.2 + 0.4 kg/ha followed by two postemergence applications of sethoxydim at 0.56 kg/ha (high). In the fallow-only system, the high level of herbicide usage was more effective than the medium level in preventing johnsongrass development. The high level was also more effective than plowing only where plowing was limited to June and July (2 yrs) but not where an additional plowing was performed in August (1 yr). Planting wheat in the winter, following the destruction of the second ratoon, did not decrease total weed cover and johnsongrass foliar cover and panicle production. Johnsongrass control in the option involving early fallow disking and double-drilling of soybeans on reformed 1.8 m sugarcane rows treated with trifluralin + metribuzin at 1.1 + 0.4 kg/ha (medium level) was equivalent to fallowed plots receiving the high level of herbicide usage. The results indicate that herbicide usage is essential to insure consistency in a johnsongrass control program for fallowed sugarcane fields and that the growing of soybeans during the fallow period provides an additional increment of control over herbicide treatment alone.

### INTRODUCTION

In Louisiana, sugarcane (*Saccharum* interspecific hybrids) is routinely grown as a 3-yr crop with annual harvests on raised beds spaced 1.8 m apart. Cultural practices conducive to successful sugarcane growth are also favorable for growth of perennial johnsongrass [*Sorghum halepense* (L.) Pers.], a major weed of sugarcane in Louisiana. Because selective herbicides provide only partial control of rhizome johnsongrass in sugarcane, the potential for yield suppression from johnsongrass competition increases with each crop season with the severity of this competition, often reducing the crop's longevity.

Fields are destroyed by disking in late fall or spring following the harvest of the last ratoon crop and remain fallow during the spring and summer months. Disking may be repeated six or more times during the fallow period to destroy johnsongrass rhizomes which may have developed during the 3-yr crop cycle and to deplete soil stores of weed seeds. Success of this program is weather-related with rainfall during the summer months frequently preventing these timely diskings. This may allow newly-emerging johnsongrass seedlings to replenish the soil reserves of seed and rhizomes depleted earlier.

Chemical-fallow programs employing the use of preemergence herbicides have been developed for several crops to minimize erosion and/or to reduce soil moisture loss associated with frequent diskings (1, 2, 3). In Louisiana, metribuzin [4-amino-6-(1,1-dimethylethyl)-3-(methylthio)-1,2,4-triazin-5(4H)-one] has been shown to provide 8 to 10 weeks of seedling johnsongrass control in fallowed sugarcane fields that were previously disked at frequent intervals to destroy existing rhizomes (5). Obtaining preemergence herbicide persistence for only a portion of the 5- to 6-month fallow period without the use of postemergence herbicides to destroy escaped weeds requires high rates in an area of the field where no short-term economic gain can be anticipated. This study was initiated to investigate the feasibility of using annual crops during the fallow period to suppress johnsongrass growth and, thereby, reduce herbicide rates, and to provide additional farm income.

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## MATERIALS AND METHODS

Fields of second ratoon sugarcane growing on a Mhoon soil (fine-silty, mixed nonacid, thermic Typic Fluvaquents) and severely infested with rhizome johnsongrass were selected. Immediately after sugarcane harvest on December 9, 1981 (study A), October 25, 1982 (study B), and December 12, 1984 (study C), the sugarcane ratoon, associated plant residues, and the existing beds were destroyed by four successive passes with a disk harrow. A level seedbed was formed using two passes with a S-tined seedbed conditioner prior to drill-seeding wheat (*Triticum aestivum* L.) at a 21 cm drill spacing on designated plots on December 12, 1981, (study A), December 23, 1982 (study B), and December 18, 1984 (study C). Because of a poor stand in 1984, the entire field was redisked once and a new seedbed prepared using one pass with the S-tined seedbed conditioner on March 12, 1985. Designated wheat plots were reseeded on March 13, 1985. Since little was known about wheat performance in southeast Louisiana, several cultivars were evaluated. In studies A and B, wheat plots were divided in half lengthwise and cultivars 'Coker 65-15' and 'Florida 301' planted in study A and cultivars 'Coker 762' and 'Coker 797' planted in study B. For study C, the entire plot was seeded to 'Coker 747'.

Conventional 1.8 m wide by 35 cm high sugarcane rows were reformed on the plots not planted to wheat on March 16, 1982 (study A), March 26, 1983 (study B), and April 11, 1985 (study C). Row buildup was accomplished using a plow to mark wheel furrows followed by two passes with a four-disk per gang rolling bed chopper to build up the rows. Weed vegetation was not destroyed prior to row formation. Soybeans [*Glycine max* (L.) Merr. (cultivar 'Forrest')] were seeded on May 6, May 27, and May 3, in two drills spaced 61 cm apart on top of each 1.8 m bed in studies A, B, and C, respectively. Prior to planting soybean seeds were coated with a commercial mix of *Rhizobium* bacterium. To meet the fertility needs of the young plants in the interim between inoculation and symbiotic nitrogen fixation by the nodulated bacteria, ammonium nitrate (33-0-0) was banded between the two drills of soybeans at 11 kg N/ha when soybeans were in the two to three leaf stage.

Within each cropping system, three herbicide levels (none or low, medium, and high) were imposed to produce various levels of johnsongrass control (Table 1).

Table 1. Crop options and imposed herbicide levels evaluated in fallowed sugarcane fields.

Management option	Herbicide level	Treatment description	Herbicide rates (kg/ha)
Fallow only	Low/none	2 plowings (1983 and 1985) 3 plowings (1982)	--
	Medium	Trifluralin + metribuzin	1.1 + 0.4
	High	Trifluralin + metribuzin + 2 (sethoxydim)	2.2 + 0.4 + 2 (0.56)
Wheat + fallow	Low/none	2 plowings (1982) 1 plowing (1983 and 1985)	--
	Medium	Trifluralin + metribuzin	1.1 + 0.4
	High	Trifluralin + metribuzin 2 (sethoxydim)	2.2 + 0.4 + 2 (0.56)
Fallow + soybeans	Low/none	Metribuzin only	0.4
	Medium	Trifluralin + metribuzin	1.1 + 0.4
	High	Trifluralin + metribuzin + 2 (sethoxydim)	2.2 + 0.4 + 2 (0.56)

Preplant incorporated applications of trifluralin [2,6-dinitro-N, N-dipropyl-4-(trifluoromethyl)benzenamine] were made to designated fallow only and fallow + soybean plots on May 5, May 26, and April 20 and on wheat + fallow plots on June 16, June 16, and June 6 following wheat harvest and row buildup in studies A, B, and C, respectively. Trifluralin was selected for this study because it is labelled for use on soybeans and sugarcane and because it controls johnsongrass germinating from both seed and rhizome buds (6). Trifluralin was incorporated to a depth of 10 cm with a rotary tiller within 2 hours of application. To enhance the degree of broadleaf weed control with a minimum of soybean injury, metribuzin at 0.4 kg/ha was applied as a sequential preemergence treatment after trifluralin incorporation. All plots, regardless of herbicide level, were subjected to rotary tillage at the time of trifluralin application. In addition to doubling the rate of trifluralin, plots designated to receive the high level of herbicide usage also received two postemergence applications of sethoxydim [2-[1-(ethoxymino)butyl]-5-[2-(ethylthio)propyl]-3-hydroxy-2-cyclohexen-1-one] at 0.56 kg/ha on June 22 and July 6 (study A), July 18 and August 30 (study B), and June 17 and August 2 (study C) when johnsongrass was 60 to 152 cm tall. All herbicides were applied broadcast at 375 l/ha.

Where no herbicides were applied in the fallow only and wheat + fallow systems, weeds were controlled by plowing with an implement, consisting of a double lister plow and bed choppers, designed to open (15 cm depth) and reclose 1.8 m sugarcane rows in one operation. Fallow plowing was attempted at intervals of 3 to 4 weeks beginning after row build-up and rotary tillage of all plots within a management option. In the fallow only option, plowing was performed on June 16, July 6, and August 10, in study A. Early August rainfall limited this operation to June 16 and July 14 and June 6 and July 11 for studies B and C, respectively. Plots receiving no herbicide in the wheat + fallow option were plowed twice in study A (July 6 and August 10) and only once in studies B (July 14) and C (July 11). Since rainfall prevented a third tillage operation in mid-August in studies B and C, no additional tillage was attempted prior to the September ratings. Cultivation could not be performed in the fallow + soybean option. Therefore, metribuzin at 0.4 kg/ha was applied preemergence after planting, to represent the low level of herbicide usage, primarily to control broadleaf weeds.

Predominant weeds in these fields included: seedling johnsongrass, annual sedge, (*Cyperus compressus* L.), junglerice [*Echinochloa colonum* (L.) Link.], southern crabgrass [*Digitaria ciliaris* (Reta.) Koel.], red morningglory (*Ipomoea coccinea* L.), entireleaf morningglory (*Ipomoea hederacea* var. *integriscula* Gray), cutleaf groundcherry (*Physalis angulata* (L.) St. Hil.), spotted spurge, (*Euphorbia maculata* L.), texas weed [*Caperonia plaustris* (L.) St. Hil.], and spreading dayflower (*Commelina diffusa* Burm. F.), with grasses being the predominant weed species.

Weed control efficacy for the various herbicide levels was determined in mid to late September by visually estimating the percentage of the surface area of each plot that could be covered by the foliage of each weed present (5). In effect, this was an estimate of the leaf area index of each weed species. Johnsongrass panicles on each plot row were also counted at this time.

The experiment was a three crop option by three herbicide level factorial arranged as a randomized complete block designed with four (studies A and B) or five (study C) replicates per treatment. Experimental plots were 5.3 m wide and 15.3 m long. Data for each study were subjected to statistical analysis and means were separated using Fisher's Least Significant Different Test.

## RESULTS AND DISCUSSIONS

Crop yields. Wheat yields averaging 1196 and 3622 kg/ha were obtained in 1982 for Coker 68-15 and Florida 301, respectively. Differences in yield resulted from a severe infection of leaf rust (*Puccinia recondita* F. sp. *tritici*) and stem rust (*Puccinia graminis* F. sp. *tritici*) on Coker 68-15. In 1983, yields of 1740 and 1270 kg/ha were obtained for Coker 762 and Coker 797, respectively. During the pollination and early milk stages of wheat development in 1983 (March 15 to April 15), rain totalling 28.2 cm fell during 14 days of the period. These cloudy and wet conditions probably contributed to the low cultivar yields. In 1985, the short growing season caused by replanting resulted in a yield of 1492 kg/ha for Coker 747.

Soybeans were not harvested in these studies because the late maturity dates of current recommended soybean cultivars would have jeopardized sugarcane planting during the traditional planting period of late August and September. Delaying the planting of sugarcane would then cause conflicts with the sugarcane harvesting season. Soybeans would, thus, be better suited as a green manure crop turned under 4 to 6 weeks prior to

sugarcane planting. This would limit potential benefits from the use of soybeans unless an earlier maturing cultivar can be identified for this area.

**Weed responses.** Management options by herbicide level interactions were observed at the  $P < 0.05$  level in 1982 and 1983 and at the  $P < 0.10$  level in 1985 for total weed cover and johnsongrass panicle production. Interaction-indicating F-values of 24.75, 3.74, and 2.11 (total weed cover) and 27.04, 34.94, and 2.44 (johnsongrass panicle production) were obtained in 1982, 1983, and 1985, respectively. Similar interactions at the  $P < 0.05$  level were observed for johnsongrass foliar cover in 1982 and 1983, where F-values of 2.78 (1982) and 6.93 (1983) were obtained, but not in 1985, where an F-value of 1.33 was obtained. These interactions indicate that weed responses were generally a function of both the crop and herbicide management option selected for all parameters.

Where plowing represented the low level of herbicide usage in plots fallowed during the summer months (fallow only and wheat + fallow options), total foliar cover and johnsongrass foliar cover was lower in 1982 than in 1983 and 1985, apparently because plots received an additional plowing on August 10, 1982 (Table 2).

Table 2. Effects of crop-herbicide management options on total weed (TW) and johnsongrass (JG) foliar cover in fallowed sugarcane fields<sup>1</sup>.

Management Option	Herbicide level					
	Low/None		Medium		High	
	TW	JG	TW	JG	TW	JG
-----(% cover)-----						
Study A (1982)						
Fallow	11	8	92	65	65	8
Wheat + Fallow	2	1	98	47	78	24
Fallow + Soybeans	61	59	33	31	5	2
LSD 0.05 =	23	8				
Study B (1983)						
Fallow	204	22	205	66	128	9
Wheat + Fallow	118	18	234	56	112	0
Fallow + Soybeans	159	52	98	6	67	6
LSD 0.05 =	68	10				
Study C (1985)						
Fallow	168	27	181	51	124	4
Wheat + Fallow	209	65	185	56	147	3
Fallow + Soybeans	192	69	169	42	62	1
LSD 0.10 =	50	27				

<sup>1</sup> Foliar cover is a visual estimate of the percentage of the surface area of each plot that could be covered by the foliage of each weed present, i.e. leaf area index by weed species.

Junglerice and the other small-seeded annual weeds germinated with johnsongrass in plots receiving no herbicide and only two plowings (studies B and C). Under such circumstances the vegetative development of johnsongrass was hindered; hence, its foliar cover was reduced by competition from these weeds. An interaction was observed because when soybeans were included with the low level of herbicide usage, small-seeded annual



weed development was suppressed more than johnsongrass development. As a result, total weed cover was lower and johnsongrass foliar cover in these plots was generally higher and often equalled that of plots that received only June and/or July plowings in the fallow only and wheat + fallow options.

From observations, the medium level of herbicide usage in the fallow only and wheat + fallow options had lower densities of weeds; however, escaped weeds grew larger, producing weed covers that equaled or exceeded those in plots receiving no August plowing (low level). When soybeans were included with the medium level of herbicide usage, this was not observed because the soybeans provided additional suppression of escaped weeds.

Total weed cover was greatly reduced at the high level of herbicide usage where the rate of trifluralin was increased and two postemergence applications of sethoxydim were included. Greatest reductions were observed in plots planted to soybeans in the spring and summer months. Although not completely eliminated, johnsongrass comprised only a small percentage of the total weed cover of these plots.

Plowed plots of the fallow only option generally had fewer johnsongrass panicles than plots receiving the medium level of herbicide usage with the difference being greatest where weather permitted three plowings (study A) (Table 3).

Table 3. Effects of crop-herbicide management options on johnsongrass panicle production in fallowed sugarcane fields<sup>1</sup>.

Management option	Herbicide Level		
	Low/None	Medium	High
----- (Panicles/m of row) -----			
Study A (1982)			
Fallow	0.9	6.6	0.5
Wheat + Fallow	0.1	3.6	0.6
Fallow + Soybeans	6.4	2.7	0.2
LSD 0.05 =	2.4		
Study B (1983)			
Fallow	1.8	6.3	0.4
Wheat + Fallow	0.9	3.8	0.0
Fallow + Soybeans	6.8	0.4	0.7
LSD 0.05 =	4.6		
Study C (1985)			
Fallow	2.7	9.7	0.9
Wheat + Fallow	8.7	10.2	0.3
Fallow + Soybeans	13.3	5.8	0.0
LSD 0.10 =	7.2		

<sup>1</sup> Johnsongrass panicles were counted on each plot-row in September of each year.

Where an August plowing could not be performed, junglerice and other annual weeds germinating simultaneously with johnsongrass probably restricted the subsequent reproductive development of seedling



johnsongrass as has been noted in other weed communities (4). As a result, johnsongrass panicle production in these plots generally equaled that of plots receiving a combination of soil-applied and postemergence herbicide treatments. Where soybeans were present during the summer months, johnsongrass panicle production generally decreased as the level of herbicide usage within the program increased, with little or no difference in johnsongrass panicle production between the medium and high levels of herbicide usage being observed. In this management option, weed-weed competition was replaced by crop-weed competition. Use of the preemergence herbicides (medium herbicide level) insured the development of a competitive soybean crop early in the growing season and resulted in increased johnsongrass suppression. As a result of this suppression, additional reductions in johnsongrass panicle production did not occur with the inclusion of two postemergence applications of sethoxydim to the management option.

In summary, an intensive chemical program employing a combination of broad-spectrum soil-applied herbicide(s) and multiple postemergence herbicide applications will be required to successfully insure a depletion of the soil reserves of johnsongrass seed and rhizomes over variable environmental conditions in fallowed sugarcane fields. If the program is not intensive and only soil-applied herbicides are used, control of small-seeded annual grass and broadleaf weeds would be expected to continue for a longer period than that of johnsongrass. As a result, emerging johnsongrass could grow and develop unencumbered for space by competition from other weed species and replenish the soil reserves of seed and rhizomes. Where a preemergence herbicide treatment for grass and broadleaf weeds (crop-herbicide management options employing fallow plowing only or multiple postemergence applications of herbicides) is excluded, germination of all weed species would begin at the same time and interspecific weed competition would result in reduced johnsongrass germination and development, but the depletion of johnsongrass seed reserves in the soil would be limited by the fact that the germination of dormant johnsongrass seed was not stimulated.

Soil cover provided by a wheat crop during the early months of the fallow period would probably be of benefit by inhibiting the germination of weed seeds and johnsongrass rhizomes located near the soil surface. Direct results of this inhibition would be a reduction in tillage requirements and a partial depletion of soil reserves of weed propagules resulting from enhanced natural mortality of the propagules while they remained in a quiescence state. However, once the wheat is harvested and the land disked, additional weeds will germinate and a control strategy for the summer months will still be needed.

With soybeans as a cover crop during the summer months, johnsongrass emergence could be suppressed to the point where the crop cover would eliminate the need for summer tillage and/or high (2X) rates of trifluralin and postemergence herbicide applications. To harvest the soybeans as a cash crop and integrate this practice into sugarcane culture, earlier maturing soybean cultivars must be developed and/or sugarcane planting delayed. By planting soybeans on reformed sugarcane beds instead of the conventional "flat-culture", this delay could be shortened because existing rows could be opened and sugarcane planted with a minimum of moisture-depleting seedbed preparation.

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## SUGARCANE RESPONSES TO Mn SOURCES AND S APPLICATION ON TWO FLORIDA HISTOSOLS

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### ABSTRACT

In the Florida sugarcane industry, crop deficiencies of Mn are often observed and apparent yield declines are realized. To avoid these problems, furrow-applied Mn and elemental S are recommended at planting of sugarcane (*Saccharum* spp.) when soil pH exceeds 6.5. Sugarcane yield response to Mn and elemental S application were measured for three crops years on two Pahokee muck soils (Euic, hyperthermic Lithic Medisaprist). Two cultivars (cv. CP 72-1210 and CL 61-620) were grown, one at each location. The objectives were to examine the effectiveness of Mn and S recommendations determined from soil test information and to evaluate differences in the effectiveness of various Mn sources and elemental S on two specific soils with past histories of Mn deficiency and moderate to high soil pH. During six crop years, application of Mn had no significant effect on sugarcane yields, although application of elemental S for modification of soil pH had a moderate but inconsistent effect on yields at each location. Regardless of treatment and yield, the most significant finding was that soil pH increased after each cropping year, thus influencing the decline of leaf Mn concentration in each successive crop. These studies indicated that commercial plant application of Mn and elemental S may not always be justified under current soil testing recommendations on Florida Histosols.<sup>1</sup>

### INTRODUCTION

Recommendations of Mn and S applications on sugarcane in Florida are based on soil pH determinations from the Everglades Soil Testing Laboratory (ESTL). When the soil pH is greater than 6.0, 5.6 kg Mn ha<sup>-1</sup> (furrow-applied at planting) is recommended; when the soil pH is greater than 6.5, 575 kg S ha<sup>-1</sup> is recommended for Histosols (4). A majority of the soils used for sugarcane production are Histosols. Most of these organic soils are located in the Everglades Agricultural Area (EAA), and are shallow soils overlying calcium carbonate bedrock and marl. Although soil pH's in the EAA range from 4.0 to 8.1, a vast majority of these soils have pH's greater than 6.0 and 6.5. Therefore, it is recommended for the majority of organic soils passing through the ESTL, that Mn and S be applied.

Manganese deficiency has been a well recognized barrier to attaining high-yield crop production in the EAA (2). The need for Mn has been recognized for crops such as sugarcane, vegetables, and rice grown on organic soils of high pH (1,6,7,16). High soil pH has been recorded as the most influential factor that reduces Mn availability for many crops in the EAA, including sugarcane (6,10,11).

When the soil pH is higher than 6.5, furrow application of elemental S is recommended at planting of sugarcane. This practice is recommended on the premise that localized pH changes in the furrow will increase micronutrient (i.e., Mn) plant availability, thus increasing yields. Sulfur content of EAA soils are sufficiently high to rule out S deficiency (12). This recommendation originated from only a very few agronomic tests in the past. Stevens (17) increased recoverable sugar by 10% by applying elemental S, but did not increase cane yield. Temporary alleviation of Mn deficiency during the plant crop was attained by Andreis and Gascho (6), in which cane and sugar yields were increased by 8% and 10%, respectively. In their study, soil application of elemental S was as effective in controlling Mn deficiency as applying various Mn sources, but only during the first year of

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<sup>1</sup>Mention of a trade name, commercial product, or commercial enterprise does not constitute endorsement by the University of Florida.



production. The objectives of the studies reported herein are: to test the validity of Mn and S recommendations on high pH organic soils used for sugarcane production; and to investigate the responses of sugarcane to various Mn sources and to S application.

## METHODS AND MATERIALS

Two locations approximately two km apart in the east central EAA were used. The soil at both locations was a Pahokee muck soil (Euic, hyperthermic Lithic Medisaprist), a Histosol that accounts for about 27% of the EAA under cultivation (personal communication, S. McCollum, Soil Conservation Service, Palm Beach Co., FL). Sources and treatments of Mn and S used at each location are listed in Table 1. The treatment design was a randomized complete block, using four replications.

Table 1. Treatments and sources of Mn and S used at each location.<sup>1</sup>

Source	Product Name Manufacturer	kg ha <sup>-1</sup>	
		Mn	S
Control	-----	0.0	0.0 <sup>2</sup>
IPM	Micromix # 1225/Imperial Products, Inc.	5.6	0.0 <sup>2</sup>
MnO	Mn Oxide (52% Mn)	5.6	0.0 <sup>3</sup>
G	Granusol (40% Mn)/American Minerals Corp.	5.6	0.0
STM-5	(85% S, 5% Mn)/Eagle Pitcher	5.6	95.0
SG	Dispersul (90% S) + G (40% Mn)	5.6	95.0
O S	Only IPM minus Mn mix	0.0	0.0
280 S	Dispersul (90% S)/Chemical Enterprises, Inc.	0.0	280.0
560 S	Dispersul (90% S)	0.0	560.0

<sup>1</sup> Cultivars CP 72-1210 and CL 61-620 used one at each location.

<sup>2</sup> Included only at location two using CL 61-620.

<sup>3</sup> IPM minus Mn used for all Mn and S source treatments.

The experimental areas were prepared for sugarcane planting by rototilling and furrowing so that each plot contained four rows on 1.5 m spacings by 10 m long. At each location, soil samples were taken and submitted for analyses at the Everglades Soil Testing Laboratory, EREC, Belle Glade. Soil test values for pH, Pw, and K respectively were 6.73, 2.6 kg ha<sup>-1</sup>, and 60 kg ha<sup>-1</sup> at location 1, and 7.46, 1.8 kg ha<sup>-1</sup>, and 30 kg ha<sup>-1</sup> at location 2. Based upon soil test information, P, K, Cu, Fe, Zn, and B were applied at planting in the furrows of all plots at 37, 100, 2.2, 2.2, 2.2, and 1.1 kg ha<sup>-1</sup>, respectively. Double lines of sugarcane stalks were cut to approximately 46-cm lengths and placed in the furrows and covered. The times of planting, soil and tissue sampling, and harvesting for both locations are given in Table 2. Locations one and two were planted using sugarcane cv. CP 72-1210 and cv. CL 61-620, respectively. All cultural practices were the same as those maintained by the grower. Soils were sampled (0-15 cm depth) within each treatment plot, between planted rows of cane. Fifteen top visible dewlap (TVD) leaf blades, with mid-ribs (18), were collected from each plot from both locations during June of each growing season (Table 2). Analysis for Mn concentrations in the TVD leaf blades was determined by the dry ash combustion method (5).

Table 2. Times of planting, sampling of soil and leaf tissues, and harvesting for both cultivar locations.

Event	Crop	CP 72-1210	CL 61-620
Planting	----	30 October 1983	26 October 1984
Harvest	Plant	19 February 1985	6 March 1986
	1st Ratoon	5 February 1986	6 January 1987
	2nd Ratoon	16 December 1986	21 November 1987
Soil	Plant	21 October 1983	6 December 1984
	1st Ratoon	15 March 1985	18 March 1986
	2nd Ratoon	14 March 1986	7 May 1987
TVD Leaf	Plant	16 June 1984	22 July 1985 <sup>1</sup>
	1st Ratoon	5 June 1985	23 June 1986
	2nd Ratoon	25 June 1986	2 July 1987
Crop Age (mo.)	Plant	17.0	17.7
	1st Ratoon	12.5	10.9
	2nd Ratoon	11.2	11.4

<sup>1</sup> Sampled and analyzed by Dr. R. Illey, Applied Agricultural Research, Lakeland, FL.

From the soil test pH at both locations, both 2.2 kg Mn ha<sup>-1</sup> and 560 kg elemental S ha<sup>-1</sup> were recommended for furrow application at planting (4). Cultivar CP 72-1210 was used because it is used by the majority of sugarcane industry in Florida; cv. CL 61-620 was also used because it typically exhibits chlorotic symptoms indicating Mn deficiency early in the growing season, especially at high soil pH.

At the time of harvesting (Table 2), cane was burned to remove excess leaves and trash, and whole stalks were cut by hand at the soil surface. Tops were removed by cutting at the top hard internode. After the sugarcane stalks from each plot were weighed, 15 stalks per plot were randomly collected and passed through a three-roller sample mill for juice extraction. The crusher juice was analyzed for Brix using a refractometer (Bausch & Lomb, Inc., Rochester, NY). The juice was clarified using lead subacetate (13, p. 54), and the Pol was determined using a Rudolph Autopol IIS automatic saccharimeter (Rudolph Research, Flanders, NJ). The percent sucrose in juice was estimated using formulas developed from sucrose Pol and Brix temperature correction (CBrix) tables given by Meade and Chen (13, p. 882-885; and p. 861-862, respectively):

$$\text{Sucrose} = (\text{Pol} \times 26) / \{105.811 + [(\text{CBrix} - 150) \times 0.44]\}; \quad 1)$$

where the 20°C temperature correction for Brix is given as:

$$\text{CBrix} = \text{Brix} + [(\text{temperature} - 20) \times 0.075]. \quad 2)$$

juice purity was calculated as the percent of the ratio of sucrose to CBrix. Recoverable 96° sugar (STC, kg sugar Mg<sup>-1</sup> cane) was calculated using the formula described by Rice and Hebert (14):

$$\text{STC} = [(\text{Sucrose} \times 21.058) - (\text{CBrix} \times 6.15) \times \text{VCF}]; \quad 3)$$

where VCF is the varietal correction factor of 0.965 for cv. CP 72-1210 and assumed 1.00 for CL 61-620. From the measured tons cane per hectare (TCH, Mg cane ha<sup>-1</sup>) and STC, the tons sugar per hectare was calculated (TSH, Mg 96° sugar ha<sup>-1</sup>). Analyses of variance (ANOVA) and standard error of regression (SER) were obtained using SAS (15).



## RESULTS AND DISCUSSION

Significant ( $P>0.05$ ) declines in stalk weight, TCH, and TSH were observed at each location and after each successive crop (Table 3). No cropping year trends were observed for CBrix, sucrose, nor STC. Despite high soil pH values, there were no crop responses to any of the Mn sources at either location, although statistically significant ( $P>0.05$ ) yield responses were measured as a result of S application (Table 4). Responses to elemental S application were not high for either cultivar. Cane yield (TCH) increased 3.6 and 6.8% during the same season, 1st ratoon at location one (cv. CP 72-1210) and during the plant crop at location two (cv. CL 61-620), respectively (Tables 2 and 4). Similar yield increases have been reported by others (6,17). Assuming the current price of elemental S, the application of 560 kg of elemental S per ha, and a return of \$7-10 per metric tonne of cane, the observed yield increases would not economically justify applications of elemental S (3).

Table 3. Average yield data from both cultivar locations.

Yield Factors <sup>1</sup>	Location one			LSD <sub>.05</sub>	Location two			LSD <sub>.05</sub> <sup>3</sup>
	1	2	3 <sup>2</sup>		1	2	3	
CBrix (%)	21.60	21.40	20.10	0.20	18.20	19.80	20.30	0.20
Sucrose (%)	20.40	19.60	19.20	0.20	17.60	18.90	18.20	0.20
Stalk (kg)	1.57	1.47	1.26	0.03	1.39	1.33	1.10	0.06
TCH	136.00	123.00	105.00	3.00	121.00	114.00	82.00	2.00
STC	143.00	136.00	135.00	2.00	130.00	139.00	129.00	2.00
TSH	19.50	16.80	14.10	0.50	15.70	15.90	10.70	0.40

<sup>1</sup> TCH=cane yield (Mg cane ha<sup>-1</sup>), STC=sugar per ton of cane (kg Mg<sup>-1</sup>), and TSH=sugar yield (Mg ha<sup>-1</sup>).

<sup>2</sup> Plant crop=1, 1st ratoon=2, and 2nd ratoon=3.

<sup>3</sup> LSD<sub>.05</sub> between crops and by location.

Table 4. Significant yield responses to S application.

S Applied	Location one	Location two			
	--2 <sup>1</sup> -- TCH <sup>2</sup>	-----1----- Stalk	TCH	TSH	--2-- Stalk
kg/ha	Mg/ha	Kg	-----Mg/ha-----		Kg
0	118.5	1.34	118.5	15.40	1.31
280	125.2	1.35	120.1	15.48	1.35
560	122.8	1.47	126.6	16.13	1.43
LSD <sub>.05</sub>	6.5	0.12	3.1	0.58	0.13
Mean	123.4	1.38	121.2	15.68	1.33

<sup>1</sup> plant crop=1, 1st ratoon=2, and 2nd ratoon=3.

<sup>2</sup> TCH=cane yield, TSH=sugar yield, and Stalk-stalk weight.

At both locations, soil pH increased significantly during each crop year of sugarcane cultivation (Table 5). Although the data presented herein do not explain these observations, this occurrence is common among organic soils in the EAA in which there is high evapotranspiration bringing Ca salts to the soil surface, and in which high pH, carbonate-saturated irrigation water is used (9,12). Across all crop years and for both locations, the relationship between soil pH and TVD Mn content was significant ( $P>0.01$ ); as soil pH increased, Mn in TVD leaf tissues declined (Table 6). This observation was also made by others (6,10). At both locations, by the third year of production, the TVD Mn concentration approached the critical nutrient level of 10 ppm (8) as pH  $> 7.5$  (Figure 1). Unlike studies by others (6,10), none of the Mn or S treatments had any effect on tissue content of Mn in these studies. In studies conducted by Andreis and Gascho (6), the soil pH was raised by application of limestone in order to induce Mn deficiency. However, due to the high buffer pH capacity of the soil they used, the soil pH declined with time -- the reverse of our observations. Although not discussed by Andreis and Gascho (6), this may explain why they did not obtain crop response to Mn and S after the plant crop.

Table 5. Soil pH changes observed at both locations during three crop years of cultivation.

Source <sup>2</sup>	-----Soil pH-----						
	Location one			Location two			
	1 <sup>1</sup>	2	3	1	2	3	
Control	--	--	--	7.52	8.22	8.27	
IPM	--	--	--	7.48	8.15	8.20	
MnO	6.80	7.12	7.85	7.40	8.12	8.27	
G	6.75	7.18	7.98	7.48	8.18	8.25	
STM5	6.70	7.22	7.72	7.38	8.18	8.25	
SG	6.70	7.18	7.78	7.48	8.18	8.27	
0 S	6.80	7.30	8.02	7.62	8.18	8.27	
280 S	6.67	7.05	7.98	7.48	8.20	8.27	
560 S	6.67	7.18	7.70	7.35	8.18	8.18	
LSD <sub>.05</sub>	0.13	0.13	0.28	0.08 <sup>3</sup>	0.09	0.10	0.09 0.04
Mean	6.73	7.17	7.86	7.26	7.46	8.17	8.25 7.95

<sup>1</sup> Plant crop=1, 1st ratoon=2, and 2nd ratoon=3.

<sup>2</sup> IPM and Control treatments not included at this location.

<sup>3</sup> LSD and mean across all crops.

Table 6. Leaf TVD Mn concentrations at both locations during three crop years of cultivation.

Source <sup>2</sup>	-----Leaf TVD Mn (ppm)-----					
	Location one			Location two		
	1 <sup>1</sup>	2	3	1 <sup>3</sup>	2	3
Control	--	--	--	34	20	13
IPM	--	--	--	35	22	13
MnO	82	32	15	35	18	13
G	68	29	14	31	22	10 <sup>4</sup>
STM5	70	32	15	33	20	12
SG	59	32	15	--	20	12
0 S	73	32	14	35	17	14
280 S	68	29	16	--	23	15
560 S	68	32	14	34	25	14
LSD <sub>.05</sub>	18	9	3	--	7	5
Mean	70	31	14	--	21	13

<sup>1</sup> Plant crop=1, 1st ratoon=2, and 2nd ratoon=3.

<sup>2</sup> IPM and Control treatments not included at this location.

<sup>3</sup> Sampled without midrib; analysis by Dr. J.R. Illey, Applied Agricultural Research, Lakeland, FL 33801; some data missing, thus mean and LSD not calculated.

<sup>4</sup> 10 ppm is critical nutrient level (8).

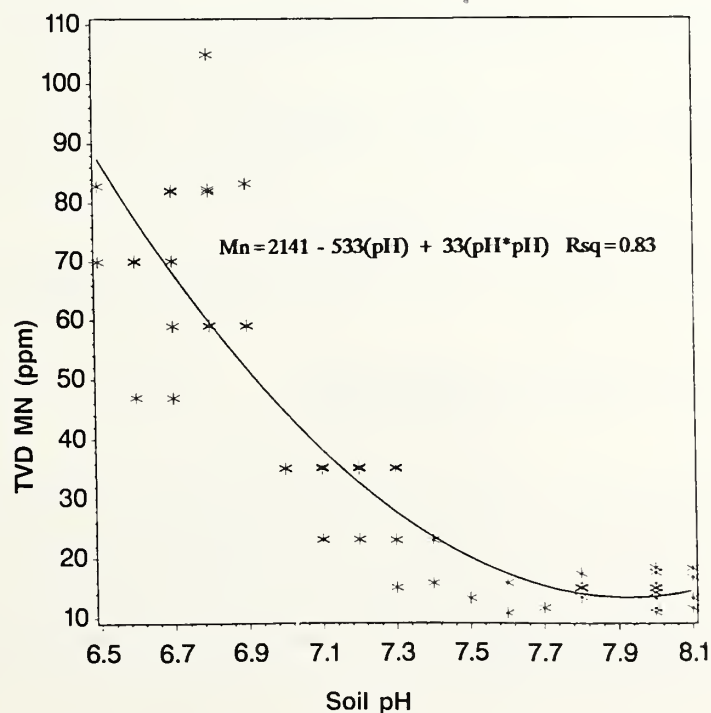


Figure 1. Effect of soil pH on sugarcane TVD leaf MN concentration from two locations and three crop years.

## CONCLUSIONS

At the locations studied, soil pH increased after each cropping year, thus influencing the decline of leaf Mn concentrations of successive crops. Although recommendations for Mn and elemental S application were given according to initial soil pH's greater than 6.5, applications had little to no effect on sugarcane yields and no effect on Mn concentrations found in TVD leaf tissues. It was therefore recognized that soil pH may not be a sufficient criteria for recommending Mn and S. Perhaps the most significant finding was that after each crop year of sugarcane cultivation soil pH increased, which resulted in significant decline of Mn content in TVD leaf tissues. These results indicate that there may be greater potential and justification to correct for Mn deficiencies in the ratoon crop, instead of at planting.

## ACKNOWLEDGEMENTS

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# EFFECT OF WHITE GRUB (*LIGYRUS SUBTROPICUS* (BLATCHLEY)) INFESTATIONS ON SUGARCANE ROOT:SHOOT RELATIONSHIPS<sup>1</sup>

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## ABSTRACT

The white grub *Ligyris subtropicus* (Blatchley) is a major insect pest of Florida sugarcane (*Saccharum* spp.). The primary impact this insect has on the sugarcane plant is through larval feeding on plant roots and underground stems. A greenhouse study was conducted to evaluate the effect of *L. subtropicus* feeding on the relative growth and development of sugarcane stalks and root systems. Third instar *L. subtropicus* larvae were introduced to the soil at the rate of 0, 2, 4, 6, and 8 larvae/plant. Overall grub survival in all infestation levels at the end of the experiment was approximately 86%. Root and stool (underground stem) dry matter were reduced linearly by increased grub infestation. Above ground dry matter was not affected by grub feeding. Root:shoot dry matter ratios decreased as number of grubs/plant increased. Juice extraction and juice quality at time of harvest was not affected by the number of grubs/plant.

## INTRODUCTION

Sugarcane (a complex hybrid of *Saccharum* spp.) is Florida's most valuable field crop, and is primarily grown in the Everglades Agricultural Area of southern Florida. Ingram et al. (5) first reported white grub injury to Florida sugarcane in 1938. Among the several white grub species currently associated with sugarcane in Florida, *Ligyris subtropicus* (Blatchley) is the species of primary economic importance (4). Currently, no chemical control is known for this pest and flooding of sugarcane fields is sometimes necessary for control (2). The primary impact this insect has on the sugarcane plant is through larval feeding on the roots and underground stems. Miller and Bell (6) reported a study in which *L. subtropicus* adults were placed in buckets containing young sugarcane plants. As the resulting larvae developed, for each gram increase in weight of the larvae, there was a corresponding decrease in plant root weight of 12.8 g. Field observations have shown that *L. subtropicus* infested sugarcane is stunted, chlorotic, and easily lodged. Sugarcane and sugar yields may be severely reduced as the result of white grub injury. Sosa (8) described a sugarcane yield reduction of 28% and a sugar yield loss of 39% attributable to a *L. subtropicus* infestation difference of 12 versus 1 grub/m row. In the same study (8), a 73% reduction in the ability of the crop to ratoon under high white grub infestation was reported.

Little information is available on the effect of white grub feeding damage to sugarcane prior to crop harvest. Yield reductions often result from stalk lodging and recumbent growth (3), which are secondary effects of white grub feeding damage. Grub destruction of plant root systems and underground supportive and regenerative tissue prior to stalk lodging may affect the potential productivity of the sugarcane crop. The objective of this study was to evaluate the effect of *L. subtropicus* feeding on root system destruction and sugarcane plant development prior to stalk lodging.

## MATERIALS AND METHODS

Sugarcane (var. CP 72-1210) was planted in a field on Pahokee muck (Euic, hyperthermic Lithic Medisaprists) on 9 February 1987, at Belle Glade, Florida. On 6 August 1987, intact sugarcane plants were transplanted into 19 L plastic buckets by removing cylindrical soil cores (25 cm diameter, 35 cm deep) containing an undisturbed sugarcane plant. The buckets were transported to a greenhouse and the plants were maintained for 39 days. Third instar *L. subtropicus* grubs, collected from commercial sugarcane fields, were then introduced

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<sup>1</sup>Florida Agricultural Experiment Station Journal Series No. 9568.

to the buckets at levels of 0, 2, 4, 6, and 8 grubs/bucket. The experiment was a randomized complete block design with 8 replications. After 42 days, the stalks were cut at the soil surface and the number of stalks/bucket and total fresh weight per bucket were recorded. Stripped stalk fresh weight and stalk height to the top visible dewlap leaf position were determined. Stalks were crushed in a 3-roller extraction mill and the crusher juice and bagasse were collected and weighed. Crusher juice brix was determined with a laboratory refractometer. The extracted juice was filtered with lead subacetate to remove suspended solids. Sucrose concentration in the filtered juice was determined with a polarimeter. Sugar concentration, expressed as g sugar/kg cane, was calculated using Arceneaux's modification of the Winter-Carp-Geerligs formula (1). Soil was gently washed from the root system and stool with a water spray. Surviving grubs were collected and root segments that had been severed by grub feeding and were no longer physically connected to the plant were discarded. Attached roots were cut from the stool, thoroughly washed with water, and retained. All plant tissue was dried to constant weight at 60° C.

## RESULTS AND DISCUSSION

The number of grubs/bucket did not affect grub survival rate and the overall survival at all infestation levels during the experiment was approximately 86%.

Table 1 presents the effect of white grub infestation on root dry matter. These root mass data represent only the remaining intact and potentially functional portion of the plant's total root system. Observations indicated that actual root mass consumption was a minor contribution to the total damage inflicted by the grubs. The major impact grub feeding had on the root system was through severing roots from the stool. Root function may have been severely impaired due to the large number of severed roots. Root dry matter/plant decreased linearly with increasing number of grubs/plant. The 8 grubs/plant treatment resulted in a 59% reduction in functional root mass versus the control.

Table 1. Effect of white grub infestation on root, stool, and aerial shoot dry matter (DM) of sugarcane.

Grubs/Plant	Root DM	Stool DM	Shoot DM
	mg/plant	g/plant	g/plant
0	435	1.60	322
2	466	1.48	347
4	379	1.24	297
6	399	1.34	322
8	178	1.11	310
Linear Regression	**	**	NS

\*\* Regression is significant at  $P < 0.01$ .

Root DM =  $540 - 29(\text{Grubs/Plant})$ ,  $r^2 = .44$ .

Stool DM =  $1.94 - 0.06(\text{Grubs/Plant})$ ,  $r^2 = .58$ .

NSRegression is non-significant ( $P > 0.05$ ).

A sugarcane stool is composed of supportive and regenerative underground stems and roots. Stool dry matter data reported in this study refers only to underground stem tissue. Stool dry matter decreased linearly with increasing number of grubs/plant (Table 1). The 8 grubs/plant treatment resulted in a 31% decrease in stool mass versus the control. This reduction in stool mass was highly localized and resulted in completely severed or highly weakened stalk bases leading to stalk lodging. Feeding damage to stool tissue may have a very



pronounced effect on the regenerative capacity of the plant due to the destruction of underground axillary buds. Sosa (8) reported a 73% reduction in the stubbling ability of sugarcane highly infested with *L. subtropicus* grubs.

During this experiment, total aerial shoot dry matter accumulation was not significantly affected by changing grub densities (Table 1). After 42 days of exposure to the highest grub infestation rate (8 grubs/plant), sugarcane plants were exhibiting leaf chlorosis and stalk lodging. At the onset of these visual plant stress symptoms, severe destruction of subterranean plant tissue had already taken place, but aerial shoot dry matter production was not reduced. It is probable that if the experiment had been continued after the 42 days, aerial production would have been severely impaired due to the reduced capacity of the plant's root system and supportive structures to sustain shoot growth. Data in Table 1 show that the severity of grub damage to the sugarcane plants was roots > stool > shoots.

Table 2. Effect of white grub infestation on root:shoot dry matter relationships of sugarcane.

Grubs/Plant	Root:Aerial shoot	Subterranean:Aerial shoot <sup>1</sup>
	mg/g	mg/g
0	1.29	6.32
2	1.29	5.69
4	1.22	5.34
6	1.26	5.63
8	0.55	4.02
Linear Regression	**	**

<sup>1</sup> Subterranean includes root and stool.

\*\*Regression is significant at  $P < 0.01$ .

Root:Aerial shoot =  $1.48 - .08(\text{Grubs/Plant})$ ,  $r^2 = .48$ .

Subterranean:Aerial shoot =  $6.95 - .23(\text{Grubs/Plant})$ ,  $r^2 = .48$ .

The effect of white grub infestation on root:shoot dry matter relationships is presented in Table 2. The relative quantity of functional root mass supporting the growth of the above ground plant decreased linearly with increasing number of grubs/plant. The ratio of total subterranean dry matter to total aerial dry matter also decreased linearly with increasing grub rate.

At the termination of this experiment, the sugarcane plants had not attained harvest maturity. This fact notwithstanding, the plants were handled as if mature millable stalks were present. Regression analyses indicated that grub infestation level did not significantly affect millable stalk fresh weight, stalk length, or crusher juice extraction. Both percent Brix and percent sucrose were low (13.5 and 10.7, respectively) and not significantly different across the range of grubs/plant treatments. The low crusher juice Brix and sucrose analyses reflected the immaturity of the milled stalks (7). Sugar concentration was also unaffected by the level of grub infestation and averaged 67.5 g sugar/kg cane. These data are in contrast with Sosa's (8) analysis of mature, field-grown cane in which a three percentage point decrease in crusher juice extraction, a two percentage point reduction in juice sucrose, and a 17% reduction in sugar concentration were disclosed due to high *L. subtropicus* grub infestation levels. In our study, the lack of harvested crop response to grub feeding pressure was most probably due to the short duration (42 days) that the plants were exposed to the grubs.

The objective of this experiment was to evaluate the effect of *L. subtropicus* feeding on root system destruction and sugarcane plant development prior to stalk lodging. At the onset of the visual plant stress symptoms of leaf chlorosis and stalk lodging due to grub feeding activity, underground plant components had already been severely damaged. Above ground shoot development and sugar production had not been affected by *L. subtropicus* infestation at this time. It is suspected that, due to the drastic root system and stool destruction



observed in this study, significant reductions in above ground plant growth, cane production, and sugar yield would have been observed under high grub infestation levels if the experiment had been continued after the onset of stalk lodging. Therefore, it appears that the detrimental effects of grub feeding damage on juice quality and sugar yield, as reported by Sosa (8), are expressed during the later phases of crop development and maturation, i.e. after the crop has lodged.

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## THE RESPONSE OF SUGARCANE SELECTIONS TO SUGARCANE BORER IN THE GREENHOUSE AND FIELD

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### ABSTRACT

A greenhouse procedure, using plants regenerated from bud-chips, was evaluated as a means of screening sugarcane (*Saccharum* interspecific hybrids) selections for resistance to sugarcane borer (*Diatraea saccharalis*). In one experiment, ten cultivars were infested in the greenhouse with first-instar larvae of the sugarcane borer; damage expressed as percent deadhearts was determined 4 weeks later. These percentages in themselves did not show differences in resistance for 9 of the 10 cultivars, but when the percentages were rated from low to high, the position of the cultivars in rank generally agreed with the relative resistance categories determined under natural infestation at the outfield stage of the USDA sugarcane selection program in Louisiana. In a second experiment, 123 sugarcane selections were first screened using greenhouse procedures and then transplanted to the field and exposed to natural sugarcane borer infestation in both plant cane and first stubble. Correlation of percentages of deadhearts in the greenhouse and bored internodes in the field were for the greenhouse test versus plant cane crop [ $r = .16$  ( $P = 0.07$ )], first stubble crop [ $r = .14$  ( $P = 0.12$ )], and the mean of plant and first stubble crops [ $r = .17$  ( $P = 0.05$ )]. Correlation of percent internodes bored between plant cane and first stubble was moderate [ $r = .43$  ( $P < 0.01$ )]. A cluster analysis using data from the three data sets revealed a group of 23 selections that were among the most susceptible and a smaller group of 12 selections that were among the most resistant in the three data sets. The results of this study suggest a relationship between the percentages of deadhearts from the greenhouse and internodes bored from the field; however, the results indicate that the reaction of cultivars measured by deadhearts in the greenhouse must be confirmed by field data before it can be used safely in selection.

### INTRODUCTION

In Louisiana, the development of a new sugarcane cultivar usually requires 13 years and involves the evaluation of initial populations as large as 100,000 seedling (2). Selections are based on some 26 evaluation criteria, many of which require detailed observations and involved procedures. Because of the time, land area, and resources required, some evaluations must be delayed until the population of candidate cultivars has been drastically reduced by selection. One such evaluation, which requires detailed studies for quantitative information, is the reaction of selections to the sugarcane [*Diatraea saccharalis* (F.)]; the most important insect pest in Louisiana sugarcane.

For more than 25 years, candidate cultivars in Louisiana have been evaluated for their response to sugarcane borers at the outfield stage of selection where only a few candidate cultivars are evaluated in larger, replicated plots. Although sugarcane borer data collected in the outfield have been useful in the management of released cultivars, such data rarely influenced the decision to release a cultivar.

Data on sugarcane borer resistance have been obtained a few years earlier in the selection program, infield stage (9), but efforts to obtain data earlier than this have met with limited success. Pan and Hensley (6) evaluated seedling progeny from several sugarcane crosses for resistance to sugarcane borer by infesting plants with first-stage larvae. Their technique appeared useful as a means of screening large numbers of seedlings, but the performance of the selected seedlings were not evaluated in field trials. Dunckelman and Legendre (4) reported that clones selected for sugarcane borer resistance as seedlings in the greenhouse were no more resistant to sugarcane borer damage than those not selected.

The purpose of this study was to evaluate greenhouse procedures for determining the response of potential new cultivars to sugarcane borer, some 3 years after initial selection, when the number of candidate cultivars has been reduced to a manageable level.

## METHODS AND MATERIALS

During the 1984 harvest season, two stalks from each of 123 selections, five stalks from the cultivars CP 48-103, CP 61-37, CP 67-412, CP 70-330, CP 72-356, CP 72-370, and NCo 310, and 75 stalks from the cultivars CP 65-357, CP 70-321 and CP 74-383 were stored (10° C) for about 4 weeks before bud-chips were excised using procedures of Ramaiah et al. (7). All bud-chips were immersed in the fungicide benomyl-[methyl-(butylcarbamoyl)-2-benzimidazolecarbamate] (0.33 g ai/l) for 10 min. before being planted in vermiculite in 50 X 35 X 8 cm metal flats. Two experiments were established at this time; one consisting of only cultivars and the other with the 123 selections and three cultivar standards.

**Evaluation of Cultivars.** This experiment contained the following 10 cultivars: NCo 310, CP 48-103, CP 61-37, CP 65-357, CP 67-412, CP 70-321, CP 70-330, CP 72-370, CP 72-356, and CP 74-383. The experiment was replicated five times and the cultivars randomly assigned to one of the two flats comprising a replication. Six bud-chips per cultivar, planted in a row, were considered a replication.

Flats were placed in a greenhouse, with a daily temperature fluctuating between 10-32° C and fertilized at bi-weekly intervals with an all-purpose water soluble plant food; concentrated to 15-30-15. When plants were about 30 cm tall, each plant was infected with four (+/- 2) laboratory-reared first-instar, sugarcane borer larvae by means of a hand-held inoculator (3, 10). Each plant was re-infested the following week with four larvae. Counts were made 4 weeks later to determine the total number of tillers and the number of sugarcane borer-killed tillers (deadhearted) for each cultivar. Data were expressed as percent deadhearts and percentages were transformed to arcsine  $\sqrt{\%}$  for analysis as a randomized complete block design.

**Evaluation of Selections.** In greenhouse evaluations, bud-chips were used in a manner similar to the cultivar test. Six bud-chips from each of 123 selections were planted in flats with each flat containing four selections, and three cultivars serving as standards; the test was replicated twice. The cultivar standards and their relative resistance ratings (based on outfield cultivar trials) were as follows: CP 74-383, highly susceptible; CP 65-357, intermediate in resistance; and CP 70-321, highly resistant. Entries were randomly assigned to each flat and to location with a flat. Plants were handled identically to plants in the cultivar test with respect to both infestation and evaluation procedures.

Flats used in the greenhouse evaluation were sprayed with the insecticide monocrotophos (dimethyl-(E)-1-methy-2-methylcarbonylvinyl phosphate] (0.84 kg ai/ha) to kill sugarcane borers, and individual plants were transferred to 7.5 cm peat-pots. Plants were then transplanted to the field in the spring to single-row plots 1.8 m long on rows 1.8 m apart in a randomized complete block design with two replications. Plants within a row were spaced 30 cm apart for a total of six plants per plot.

During 1985, plants were exposed to naturally occurring sugarcane borer. At harvest, all selections were evaluated in the plant cane crop for damage by randomly selecting 10 stalks from each plot and determining the number of internodes bored. The first ratoon crop was evaluated under natural sugarcane borer infestation. Data were taken in the same manner as the previous year and data from both crops were expressed as percent internodes bored.

Observed percent deadheart data from the cultivar standards in the greenhouse evaluation were tested for goodness to fit to the binomial distribution by chi-square. Probabilities for the binomial distribution were obtained from Beyer (1).

Cluster analysis (5), a multivariate statistical method, was used to combine the selection data from all three evaluations into a common data base for assigning selections into distinct groups. The FASTCLUS procedure (8) was used to perform a four cluster grouping on the mean damage response from the greenhouse, plant cane and first stubble field evaluations. A four cluster grouping was chosen *a priori* to create intermediate categories of resistance.

## RESULTS AND DISCUSSION

The results of the commercial cultivar test are shown in Table 1. The cultivars, except for CP 70-330, were not significantly different from each other, indicating very high variability in the greenhouse results. When



the cultivars are arranged in order of their percentages from greatest percentage of deadhearts to least, those with the highest, intermediate and lowest percentages are also those that rated similarly in outfield cultivar trials, with the exception that CP 48-103 which rated resistant in the greenhouse trial, rated susceptible in outfield cultivar trials. These data suggest a relationship in reaction of cultivars expressed as deadhearts in the greenhouse and internodes bored in the field.

Table 1. Percent deadhearts for commercial sugarcane cultivars evaluated in the greenhouse and their assigned resistant category based on outfield evaluations.

Variety	Deadhearts <sup>1</sup>	Resistance category <sup>2</sup>
	(%)	
CP 61-37	93 a	S
CP 72-356	90 a	S
CP 74-383	89 a	S
CP 72-370	89 a	IR
CP 65-357	78 a	IR
NCo 310	75 ab	R
CP 48-103	67 ab	S
CP 70-321	66 ab	R
CP 67-412	57 ab	R
CP 70-330	43 b	R

<sup>1</sup> Numbers in the same column not followed by the same letter differ significantly ( $P < 0.05$ ) as determined by the Student-Neuman-Kuels Range on the arcsine  $\sqrt{\%}$  transformation.

<sup>2</sup> Based on data from outfield cultivar trials.

Further evidence for the variability of greenhouse results was obtained from the three cultivars used as standards in the selection test. The three cultivars were planted in all 62 flats. It was decided to use only those data for each cultivar where all six bud chips had germinated, eliminating variable germination among replication which may have affected the results in Table 1.

The mean percent deadhearts and 95% confidence intervals for the 44 flats of CP 74-383 with full germination was  $87.7 \pm 4.9$ , for the 38 flats of CP 65-357 was  $67.0 \pm 9.3$  and for the 59 flats of CP 70-321 was  $68.7 \pm 7.2$ .

Frequency distributions for the proportion of deadhearts for each cultivar standard were determined in an effort to identify the sources of variability. Frequency distributions were generated by determining the number of occurrences for each discrete category. The discrete categories were zero among the six plants with deadhearts up to six of six plants with deadhearts.

The frequency distribution for the susceptible standard, CP 74-383, statistically fit a binomial ( $X^2 = 0.51$ ,  $P > .05$ ,  $df = 2$ ) while the distributions of the two resistant cultivars were bi-modal with highly significant Chi-square values when the observed frequencies were compared to those expected from the binomial distribution. The binomial distribution for CP 74-383 suggests that the probability of a plant of CP 74-383 becoming deadhearted was a random event. The bi-modality of the more resistant standards suggest that their becoming deadhearted was not random and that factors other than simply resistance were operating in the greenhouse. These factors, possibly experimental design, resulted in some cultivar reacting as resistant and others as susceptible.



Correlations for the selected cultivars between the percentages of deadhearts in the greenhouse and internodes bored in the field were  $r = .16$  ( $P = 0.07$ ),  $r = .14$  ( $P = 0.12$ ), and  $r = .17$  ( $P = 0.05$ ) for the greenhouse test versus plant cane, first stubble, and the mean of plant and first stubble, respectively. The correlation coefficient of bored internodes in the plant cane crop and first ratoon crop was  $r = .43$ , ( $P < 0.01$ ). The low levels of correlation between the reactions of cultivars to sugarcane borer in the greenhouse and field suggested the need for a statistical method to analyze whether in the range of resistance to susceptibility, there was any reaction among cultivars in which the greenhouse and field results agreed. Cluster analysis was considered an appropriate method. The results of a four-cluster analysis is presented in Table 2. Those selections assigned to cluster 1 were considered to have high resistance, cluster 2 contained selections considered to have high susceptibility, and clusters 3 and 4 were considered intermediate with responses dependent on greenhouse or field environment.

Table 3 shows the distribution of clones among quartiles from resistance to susceptibility using data sets from the greenhouse and the two field measurements within the four cluster groups. The cluster group having the most agreement between all three data sets was cluster group 2. This group was comprised of individuals with high susceptibility to borer with only the first ratoon field evaluation assigning clones to a resistant grouping. The next cluster group showing some agreement among data sets was cluster 1. The greenhouse results put all 12 (100%) of these selections into the resistant quartile while the plant cane evaluation assigned 4 (33%) and the first ratoon evaluation assigned 3 (25%) into susceptible quartiles. The remaining 88 clones were divided evenly between cluster groups three and four; their resistance status varied widely within and among the three data sets.

Table 2. Cluster analysis on the proportion of deadhearts from the greenhouse evaluation and of internodes bored in plant cane and first ratoon crops from the field evaluation of 123 selections<sup>1</sup>.

Cluster <sup>2</sup>	Frequency (#)	Cluster means		
		Greenhouse (%)	Plant (%)	First Ratoon (%)
1	12	20.1	12.3	23.9
2	23	85.2	27.5	35.5
3	44	85.7	23.9	12.2
4	44	54.1	15.9	25.1

<sup>1</sup> SAS procedure FASTCLUS (SAS Institute 1987).

<sup>2</sup> Pseudo F statistic = 102.88

Table 3. Distribution of selections among quartiles<sup>1</sup> within four cluster groups of Table 2.

Environment	1st Quartile (resistant)	2nd Quartile (intermediate resistant)	3rd Quartile (intermediate susceptible)	4th Quartile (susceptible)
Cluster Group 1 (n=12)				
Greenhouse	12(100%) <sup>2</sup>	----	----	----
Plant cane	6(50%)	2(17%)	3(25%)	1( 8%)
First ratoon	4(33%)	5(42%)	1( 8%)	2( 7%)
Cluster Group 2 (n=23)				
Greenhouse	----	----	13(57%)	10(43%)
Plant cane	----	----	6(26%)	17(74%)
First ratoon	----	3(13%)	5(22%)	15(65%)
Cluster Group 3 (n=44)				
Greenhouse	----	1( 2%)	22(50%)	21(48%)
Plant cane	15(34%)	18(41%)	10(23%)	1( 2%)
First ratoon	13(30%)	13(30%)	11(25%)	7(15%)
Cluster Group 4 (n=44)				
Greenhouse	14(32%)	30(68%)	----	----
Plant cane	9(20%)	13(30%)	10(23%)	12(27%)
First ratoon	13(30%)	10(23%)	14(32%)	7(15%)

<sup>1</sup> SAS procedure RANK (SAS Institute 1982).

<sup>2</sup> Number of selections (percentage of total in that cluster).

The results of this study suggest that the greenhouse data can be used only as a selection procedure to eliminate or retain the extremes in susceptibility or resistance to sugarcane borer. Further studies must be undertaken to identify all sources of variation operating within the greenhouse if the desired precision needed for selection is to be attained.

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# FAMILY PERFORMANCE AT EARLY STAGES OF SELECTION AND FREQUENCY OF SUPERIOR CLONES FROM CROSSES AMONG CANAL POINT CULTIVARS OF SUGARCANE

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## ABSTRACT

The selection scheme of the Canal Point sugarcane (*Saccharum* spp.) breeding program consists of five stages, which include Seedling, Stages I, II, III and IV. Visual selection is used in Seedling Stage and Stage I, objective selection is used in Stages III and IV, and a combination of visual and objective selection is in Stage II. From seven Canal Point cultivars used as parents, approximately 12,000 original seedlings were used to evaluate their progeny performance at early stages of selection and to evaluate the frequency of superior clones. Patterns of frequency distribution of stalk diameter of unselected samples varied among progenies with some having fairly symmetrical curves. The stalk diameter of unselected samples ranged from 12 mm to 36 mm in the Seedling Stage and from 18 to 42 mm in Stage I. When stalk diameter was the primary selection criterion for progenies in the Seedling Stage and Stage I, some parents or cross combinations produced higher rates of acceptable clones than did the other parents or cross combinations. Progeny means of measurements of juice quality were less than those of either parent, but most crosses produced some clones that exceeded the performance of either parent. If the clones advanced to the yield test in Stage IV were assumed to be superior ones, the frequency of these clones ranged from one in 1510 to one in 3917 among original seedlings of the seven cultivars used as parents. Choice of both parental clones and cross combinations affect the effectiveness of a sugarcane breeding program.

## INTRODUCTION

Evaluation of parent and progeny performance is the most important measure that a sugarcane breeder performs to determine the efficiency of his variety improvement program. Poor parents and/or crosses waste time and funds.

Skinner (12) considered the proven-cross system to be an important method to increase the efficiency of selection by raising the overall quality of original seedling populations. Buzacott (4) suggested that unless crosses are chosen that produce a reasonable percentage of seedlings with a high sucrose content, the likelihood of selecting a suitable commercial type was very remote unless huge populations were handled. Arceneaux (2) recognized that a parent must be judged on its ability to produce seedlings that are superior to existing varieties.

Several methods have been used to evaluate parent and progeny performance in sugarcane. Walker (14) utilized selection percentages from the first three stages as measures of family performance. However, Arceneaux (2) noted that progeny performance, as judged from selection rates in early rounds of screening, was not always a reliable index of value of a parent, but that rates of selection in stages approaching the commercial level were of greater practical significance. George (7) determined that the frequency curves of certain valued agronomic characters, obtained by measuring random samples of seedlings from each cross, enabled the respective merits of each cross to be determined. He also used a grade score to estimate the potential of sugarcane crosses and found that the mean grade was a good guide where difference between the means was large (8). Coleman et al. (5) used breeding rate, calculated by multiplying the percentage of superior plants for each of the evaluated characters together, to predict progeny performance and the environmental adaptation of the cross. Arceneaux et al. (3) used a factor for superior performance (FSP) approach to examine the incidence of superior seedlings from different parental sources and concluded that the high seedling performance would reflect the corresponding level of genetic potential.

A few sugarcane breeders are in favor of using proven parents rather than proven crosses (14). In Barbados, Walker (14) suggested that repeated crosses are yielding diminishing returns both in terms of improved clones and information. In Mauritius, George (7) noted that the work involved in repeated crosses is scarcely worthwhile after the initial production of between 2,000 and 3,000 seedlings. However, the changes in year to year environmental conditions might affect progeny performance. Warner (15) suggested that the superiority of breeding with successive generations of elite hybrids over repeating the crosses between the original parents.



He demonstrated that the frequency of elite seedlings increased as the successive generations of elite hybrids were advanced in the Hawaii sugarcane breeding program.

The objective of this study was to evaluate the progeny performance of eleven selected crosses in early and intermediate stages of selection as a means of providing predictive information about the breeding potential of parental clones utilized in a temperate-environment sugarcane breeding program.

## MATERIALS AND METHODS

Progenies of 11 crosses produced from seven parental clones were chosen randomly from the regular sugarcane breeding program in 1979. Characteristics of these parental clones are presented in Table 1. Both CP 63-588 and CP 70-1133 had become leading cultivars in Florida after their release. The seedlings were observed through all stages of selection. The selection procedures followed at the USDA, ARS, Sugarcane Field Station, Canal Point, Florida, are outlined in Table 2 (6,9,10). The selection scheme indicates that visual selection criteria are used in Seedling and Stage I and objective criteria in Stage IV. Both visual and objective selection standards are applied to the selection in both Stages II and III.

Table 1. Parentage, date of release and quantitative characters of 7 parental clones of sugarcane used as checks in seedling stage.

Variety	Parentage	Date of release	Stalk diameter	Stalk weight	Brix	Sucrose	Purity	S/T
			mm	kg	°	%	%	kg
CP 63-588	Cl 54-1910 x CP 57-120	1968 <sup>1</sup>	32.7±4.9	1.9±0.4	16.9±1.8	14.5±1.9	85±3	100±15
CP 65-357	CP 52-68 x CP 53-17	1973 <sup>2</sup>	24.8±1.5	1.5±0.2	18.7±0.3	16.1±0.7	86±3	112±80
CP 68-1067	CP 52-68 X CP 57-603	1975 <sup>1</sup>	31.8±2.9	1.9±0.4	17.4±0.9	14.7±1.6	84±3	102±14
CP 69-1052	CP 62-374 x CP 56-59	1979 <sup>1</sup>	27.3±1.8	1.4±0.3	17.5±0.8	14.4±2.2	82±5	98±20
CP 70-1133	67 P 6 CP 56-63	1977 <sup>1</sup>	27.8±2.3	1.6±1.3	18.8±1.1	16.7±1.2	89±2	118±90
CP 70-1547	CP 62-374 x CP 57-526	Exptl. clone	29.2±2.8	1.6±0.6	17.7±0.2	14.4±1.4	81±1	97±14
CP 71-1442	CP 59-73 x CP 56-63	Exptl. clone	28.2±2.7	1.6±0.4	16.5±1.1	13.8±1.6	83±5	94±14

<sup>1</sup> Released by the U. S. Department of Agriculture, Florida Agricultural Experiment Station and Florida Sugar Cane League, Inc.

<sup>2</sup> Released by the U. S. Department of Agriculture, Louisiana Agricultural Experiment Station and American Sugar Cane League of the USA, Inc.

True seed were planted in flats in the greenhouse in January 1979. Seedlings were kept in the greenhouse until mid-April and then transplanted to the field in two rows 1.5 m apart with 0.3 m between seedlings within a row. Single bud cuttings of the parental clones were planted along with the seedlings of each cross as standards. In early December, stalk number, diameter (at a height of 0.5 m above ground level), and height (as an average of 5 stalks per seedling) were taken on a random sample of 100 seedlings from each cross. One stalk, from each of those 100 seedlings and from the selections from the remaining regular selection was cut 1 m long and advanced as an entry for evaluation in Stage I in December 1979. Each 1-m long stalk was planted as a single plot in rows 1.5 m apart and 0.6 m between plots. Data on three characters (stalk number, stalk diameter, and height) were collected in Stage I from the 100 randomly selected clones of each cross in January 1981. Selection of regular Stage I clones was conducted in September 1980. A 10-stalk seed cane sample was cut from each selected clone in Stage I and used to establish a 2-row 4.6 m long plot in Stage II during October 1980. The number of millable stalks in each plot was determined during August 1981 and a 10-stalk sample from each plot was taken for juice analysis in October. Sugar yield was estimated according to the modified Winter-Carp-Geerligs formula (1). CP 63-588 was used as the standard cultivar in Stage II. By using both visual and objective selection standards, a total of 105 clones (131 clones have been used since 1987) from Stage II test was advanced to the Stage III test. After having been tested for two years (plant cane and first stubble) at four locations across the major cane production areas, 8 to 11 top performing clones were advanced to the Stage IV test at eight locations for three years.

Mean differences of the various characters among the 11 crosses (Table 3) were tested for significance by Duncan's Multiple Range Test(13).

Table 2. The selection scheme of the Canal Point (CP) sugarcane breeding program.

Original Seedlings		80,000 - 1000
25.6 cm spacing apart between seedlings, 1.52 m between rows	↓	Selection made on 12-month-old seedlings; visual (subjective) selection criteria: vigor, stalk diameter, stalk solidness, stalk height, stalk number erectness, freedom from major disease.
One crop (plant cane)		
Stage I	↓	5,000 - 12,000 clones
3.04 m, single stalk plots; 1.52 m between rows		Selection made on 10-month-old plant cane clones; visual (subjective) selection criteria same as seedling stage; permanent C.P. number assigned to each selected clone.
One crop (plant cane)		
Stage II	↓	1,200 - 1,500 clones
Two-row, 3.04 m x 4.56 m plot; one location		Selection made on 12-month-old plant cane clones; visual selection criteria same as seedling stage; the objective selection criteria include Brix, sucrose, purity, sugar and cane yield, stalk weight.
One crop (plant cane)		
Stage III	↓	105 - 131 clones
Two-row, 3.04 m x 4.56 m plot; 2 replication; 4 locations;		Selection made on 12-month-old plant cane and first stubble; visual and objective selection criteria same as in Stage II
2 crops (plant cane and 1st stubble)		
Stage IV	↓	8 - 11 clones
Four rows, 6.08 m x 10.64 m; 4 replications, 9 locations;		Visual and objective selection criteria same as in Stage III. Samples taken at preharvest and harvest; selection standards for release decided by the Florida Sugarcane Variety Committee.
3 crops (plant cane, 1st and 2nd stubble)		
Commercial C. P. Cultivars		

## RESULTS AND DISCUSSION

The percent frequency distribution of millable stalk diameter of unselected samples in both Seedling Stage and Stage I is given in Table 3. Results from both stages indicated that there was a wide range of distribution of stalk diameter in each of the 11 crosses. In most cases, the range of distribution for stalk diameter was narrower in Stage I than in Seedling Stage, but the shapes of the frequency distributions were very similar to each other between stages.

Table 3. Frequency distribution (%) of millable stalk diameter of unselected populations of 11 crosses of sugarcane at Seedling and Stage I.

Cross		Percent progeny with stalk diameter (mm) greater than or equal to:																Mean	CV(%)
		12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42		
CP 65-357 x CP 63-588	Seedling		1	1	4	15	23	26	20	3	5	2		1				22 ab <sup>1</sup>	12
	Stage I						2	8	21	26	22	16	4	1				26 b	11
CP 65-357 x CP 69-1052	Seedling		4	7	15	15	14	23	15	5	1	1						21 ab	19
	Stage I					4	2	14	21	21	26	9	5					25 b	13
CP 65-357 x CP 70-1133	Seedling				7	21	24	30	10	5	3							22 b	14
	Stage I						1	12	21	31	20	11	3					25 b	11
CP 68-1067 x CP 63-588	Seedling					7	13	18	22	22	13	4		1				24 cd	13
	Stage I							1	1	9	24	26	20	11	7	1		30 dd	10
CP 68-1067 x CP 69-1052	Seedling		1	3	10	8	27	24	18	4	5							24 cd	14
	Stage I						1	4	11	22	26	21	9	6	2	2		30 dd	12
CP 68-1067 x CP 70-1133	Seedling		1		3	13	18	26	18	13	5	2	1					25 d	13
	Stage I							2	5	14	30	21	18	6	4			30 d	10
CP 70-1547 x CP 63-588	Seedling	1		1	2	7	15	20	17	16	12	6	2	1				25 d	16
	Stage I							2	6	9	19	24	12	10	8			28 c	11
CP 70-1547 x CP 69-1052	Seedling	1		1	28	7	8	18	26	19	5	3						23 c	18
	Stage I							3	4	16	31	23	15	6	2			28 c	11
CP 70-1547 x CP 70-1133	Seedling			9	17	18	29	14	13	3	1							22 b	17
	Stage I						2	4	4	21	35	15	11	6	2			28 c	12
CP 71-1442 x CP 63-588	Seedling				5	17	14	21	29	14	5	2	3					24 cd	17
	Stage I				1	6	12	19	16	19	16	6	5	1				26 b	15
CP 71-1442 x CP 70-1133	Seedling	2	9	11	22	17	18	17	4	1	1							19 a	19
	Stage I				1	2	16	19	21	18	12	7	3					23 a	15

<sup>1</sup> At separate selection stage, means not sharing a common letter differ significantly at the 5% level of probability according to Duncan's New Multiple Range Test.

If the culling level for stalk diameter was set at 28 mm in the Seedling Stage, an average of 20.28% of the seedlings would be acceptable. Crosses CP 71-1442 x CP 70-1133 and CP 70-1547 x CP 70-1133 had the lowest percentage of acceptable clones (4% and 2%, respectively) while CP 68-1067 x CP 63-588 and CP 68-1067 x CP 70-1133 had the highest percentage of acceptable clones (40% and 39%, respectively). Among the four female parents examined, progeny of CP 68-1067 had the highest percentage of acceptable seedlings (42.67%), and CP 65-357 had the lowest percentage of acceptable progeny (8.33%). Among the three male parents, CP 63-588 had the highest percentage of acceptable progeny (27.75%), CP 69-1052 was next (20.33%), and CP 70-1133 was the lowest (13.25%).



Sugarcane plants in Seedling Stage are generally smaller because they are grown from true seed whereas sugarcane plants in Stage I are larger because they are propagated from vegetative cuttings. Average stalk diameter, from the same unselected progenies tested in Stage I, was about 6 mm larger than that in the Seedling Stage. Therefore, the culling level for the stalk diameter was set at 34 mm for Stage I. The average percentage of acceptable clones was 20.85%, which was nearly the same level of acceptability as in the Seedling Stage (Table 3). CP 68-1067 x CP 70-1133 had the highest percentage of acceptable progeny (40%) and CP 71-1442 x CP 70-1133 had the lowest percentage of acceptable progeny (3%) in Stage I. Progeny of CP 68-1067 had the highest and that of CP 65-357 had the lowest percentage of acceptable clones with a culling level for stalk diameter at 34 mm, as was the case in the seedling population. Both male parents, CP 63-588 and CP 69-1052, had similar numbers of acceptable progenies (21.25% and 22.67%, respectively) in Stage I. These results indicated that the frequency distribution patterns for stalk diameter in both the Seedling Stage and Stage I of unselected samples were different among crosses and repeatable among selection stages. George (7) reported that the distribution curves for yield showed that differences due to genotype were consistent and indicative of the selection potential of each cross. The means and coefficients of variation (CV %) for stalk diameter of the unselected progenies of 11 crosses in both Seedling Stage and Stage I are presented in Table 3. Progeny of crosses with either CP 68-1067 or CP 70-1547 as a female parent produced larger diameter stalks than did the other two female parents (CP 65-357 and CP 71-1442) in both stages. Most crosses had a slightly larger CV % for stalk diameter in the Seedling Stage than in Stage I.

Stalk diameter has been reported to be a better selection criterion because its repeatability in early stages of selection is higher than that of either stalk number or Brix (9). This trait was chosen for further examination of the progeny performance. The percentage of acceptable clones (stalk diameter  $\geq 28$  mm in Seedling Stage and stalk diameter  $\geq 34$  mm in Stage I) and the actual selection rate of the eleven crosses are given in Table 4. The selection rate was strongly dependent on the parents. Progenies from two female parents, CP 68-1067 and CP 70-1547, gave a higher selection rate in all three stages than did the other two female parents, CP 65-357 and CP 71-1442. If the selection rate in these two early selection stages was used as the measurement of combining ability (11), the results indicated that CP 68-1067 as female had the best general combining ability. Five crosses, CP 68-1067 x CP 65-588, CP 68-1067 x CP 69-1052, CP 68-1067 x CP 70-1133, CP 70-1547 x CP 63-588 and CP 70-1547 x CP 69-1052, express very good specific combining ability when the selection rates was used as a measure of their progeny performance.

Table 4. Percentage of acceptable clones (stalk diameter  $\geq 28$  mm in Seedling Stage and  $\geq 34$  mm in Stage I) and actual selection rate.

Female	Seedling Stage	Male				Stage I	Male			
		CP 63-588	CP 69-1052	CP 70-1133	Avg.		CP 63-588	CP 69-1052	CP 70-1133	Avg.
CP 65-357	Accept. Seedlings <sup>1</sup>	10.00	7.00	8.00	8.30	Accept. clones	5.00	5.00	4.00	4.70
	Act. selection	7.80	9.75	10.52	9.36	Act. selections	1.26	0.97	1.63	1.26
CP 68-1067	Accept. seedlings	40.00	27.00	39.00	35.30	Accept. clones	39.00	40.00	49.00	42.70
	Act. selections	18.79	21.49	21.17	20.48	Act. selections	3.98	2.69	5.87	4.18
CP 70-1547	Accept. seedlings	37.00	27.00	4.00	22.70	Accept. clones	30.00	23.00	19.00	24.00
	Act. selections	19.15	9.95	18.14	15.75	Act. selections	3.19	1.85	2.26	2.43
CP 71-1442	Accept. seedlings	24.00	-	2.00	(13.00)	Accept. clones	11.00	-	3.00	(7.00)
	Act. selections	8.94	-	7.18	( 8.06)	Act. selections	0.50	-	1.22	(0.86)
Avg.	Accept. seedlings	27.80	(20.30)	13.20		Accept. clones	21.20	(22.70)	18.80	
	Act. selections	13.80	(13.70)	14.10		Act. selections	2.23	( 1.84)	3.25	

<sup>1</sup> Acceptable seedlings were selections made based on the measurement of stalk diameter and the actual selection rate was obtained under a combination of visual (subjective) selection criteria.

The correlations between the percent acceptable clones based on the measurement of stalk diameter alone in both Seedling Stage and Stage I and the actual selection rate based on the visual (subjective) selection criteria alone in Seedling and Stage I or based on both visual and objective selection standards in Stage II and the subsequent stages of selections are shown in Table 5. The correlation of percent acceptable clones between



the Seedling Stage (the culling level for stalk diameter at 28 mm) and Stage I (the culling level for stalk diameter at 34 mm) was highly significant ( $r = 0.850$ ). The percent acceptable clones in the Seedling Stage was significantly correlated with the actual selection rate in Stages I and II ( $r = 0.679$  and  $0.770$ , respectively), but it was not significantly correlated with the actual selection rate in the Seedling Stage ( $r = 0.585$ ). The percent acceptable clones in Stage I at the culling level of 34 mm for the stalk diameter was highly correlated with the actual selection rate in all three stages.

Table 5. Correlation coefficients for percent (%) acceptable clones based on stalk diameter and actual selection rate in the early selection stages of sugarcane variety development program.

	% acceptable clones (stalk diameter $\geq 34$ mm) Stage I (unselected)	Actual selection rate in			n
		Seedling	Stage I	Stage II	
% acceptable clones (stalk diameter $\geq 28$ mm) in Seedling Stage (unselected)	0.850**	0.585NS	0.679*	0.770**	
% acceptable clones (stalk diameter $\geq 34$ mm) in Stage I (unselected) sample directly advanced from Seedling Stage		0.878*	0.852**	0.802**	
Actual selection rate in:					
Seedling			0.808**	0.705*	
Stage I				0.893**	

NS = Non-significant at the 5% level of probability; \*, \*\*, Significant at the 5% and 1% levels of probability, respectively.

The seedlings that were advanced to Stage IV of the regular sugarcane breeding program were assumed to be elite clones as shown in Table 6. The average selection rate was one in 2,300 seedlings over all crosses in the program to reach Stage IV test whereas the selection rate was one in 1,200 seedlings from crosses of the selected parental clones. During the process of intense selection, these selected parents might have accumulated more elite genes than did the other parents as reported by Warner (15). In the 1979 seedling program, the crosses made from these seven parents produced approximately one elite seedling in 2,000 seedlings tested. Based on the frequency of elite seedlings from these crosses, there should be 30,000 to 40,000 seedlings planted to produce one cultivar for commercial production.

In the Canal Point (C.P.) cooperative sugarcane cultivar development program in Florida, both visual and objective selection standards were applied in the evaluation of the Stage II test before the superior clones were selected for advancement to the Stage III test. The means and ranges for stalk weight and quantitative measures of juice quality of selected clones from eleven crosses tested in Stage II are summarized in Table 7. Progeny means of all characters to measure juice quality were less than those of their parents, but most crosses produced at least some progenies that exceeded the range of parental characteristics. Transgressive segregation provide sugarcane breeders the opportunity to obtain clones which are superior to the parental clones. Sugarcane is a vegetatively propagated crop. Once the superior segregants have been detected, the genotypic characteristics of the clones can be fixed. Among the eleven crosses, CP 65-357 x CP 69-1052 and CP 71-1442 x CP 70-1133 did not produce any clones with transgressive recombinations for Brix, % sucrose, and S/T. None of their progenies tested in Stage II was selected for advancement to Stage III. One cross, CP 70-1547 x CP 70-1133, had more than 1000 seedlings in the initial stage. There were 198 clones obtained after the first round of selection (clones advanced from Seedling to Stage I) and 21 clones obtained after the second round of selection (clones advanced from Stage I to Stage II), but none of these 21 clones tested in Stage II were selected for planting in Stage III because of their low sucrose content and sugar yield. Therefore, parents, that can produce progeny with a high frequency of transgressive recombination for both cane yield and juice quality should provide the best opportunity for sugarcane breeders to select clones superior to parents. Although transgressive recombinations allow selection of superior clones, their performance can be caused by environmental influence rather than

improved genetic potential. Therefore, clones must be evaluated in different years and at different locations in replicated tests so that only superior clones, with improved genetic potential, will be released for commercial production.

Table 6. The total number of seedlings and the selection rate (%) in seedlings, Stage I, and Stage III for the CP 80-series.

	Seedling Number	Stage I		Stage II		Stage III		Selection rate as percentage of original %
		Number	%	Number	%	Number	%	
CP 65-357 x CP 63-588	948	61	6.43	12	19.67	2	16.67	0.21
CP 65-357 x CP 69-1052	309	16	5.18	1	6.25	0	0.00	0.00
CP 65-357 x CP 70-113	801	84	10.58	11	13.10	1	9.09	0.12
CP 68-1067 x CP 63-588	1314	224	17.05	45	20.09	5	11.11	0.38
CP 68-1067 x CP 69-1052	1574	329	20.90	36	10.94	7	19.44	0.44
CP 68-1067 x CP 70-1133	1031	222	21.90	63	28.38	12	19.05	1.16
CP 70-1547 x CP 63-588	1083	190	17.54	31	16.32	8	25.81	0.74
CP 70-1547 x CP 69-1052	909	85	9.35	15	17.65	1	6.67	0.11
CP 70-1547 x CP 70-1133	1068	198	18.54	21	10.61	0	0.00	0.00
CP 7-1442 x CP 63-588	1016	56	5.51	2	3.57	1	50.00	0.10
CP 70-1442 x CP 70-1133	425	24	5.65	5	20.83	0	0.00	0.00
Total of 11 crosses	10,478	1404	13.40	242	17.24	37	15.19	0.35
Grand Total	46,139	5976	12.95	1278	21.38	105	8.22	0.23

Table 7. Means and ranges of the eleven crosses for Stalk weight, Brix, Sucrose, Purity and S/T in Stage II.

Cross	Stalk Weight		Brix		Sucrose %		Purity %		S/T	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
CP 65-357 x CP 63-588	1.9 $\pm$ .5	1.1-3.0*	16.4 $\pm$ 2.5	13.9-19.0*	13.1 $\pm$ 3.7	9.4-16.0	80 $\pm$ 9.0	65-92*	88 $\pm$ 6.4	55-111
CP 65-357 x CP 69-1052	1.9 $\pm$ .1	1.9-2.0*	17.3 $\pm$ 1.8	16.4-18.3	13.9 $\pm$ .1	13.9-13.9	88 $\pm$ 9.6	88-89*	96 $\pm$ 4.7	90-96
CP 65-357 x CP 70-1133	1.7 $\pm$ .2	1.3-2.0*	16.8 $\pm$ 2.0	15.1-18.9*	13.3 $\pm$ 3.1	11.3-16.7*	79 $\pm$ 20.8	72.88	89 $\pm$ 11.8	72-118*
CP 68-1067 x CP 63-588	2.1 $\pm$ .4	1.4-3.2*	16.2 $\pm$ 2.7	12.7-18.8*	13.5 $\pm$ 3.7	8.3-16.8*	83 $\pm$ 10.1	67-90	93 $\pm$ 4.3	52-121*
CP 68-1067 x CP 69-1052	2.0 $\pm$ .4	1.5-2.0*	16.6 $\pm$ 1.4	13.4-19.1*	13.9 $\pm$ 3.0	10.0-16.9	84 $\pm$ 9.3	67-92*	96 $\pm$ 4.7	63-125*
CP 68-1067 x CP 70-1133	2.1 $\pm$ .5	1.4-3.5*	16.3 $\pm$ 2.2	12.3-19.9*	13.5 $\pm$ 2.9	10.0-18.3*	83 $\pm$ 6.9	73-92*	92 $\pm$ 3.3	62-132*
CP 70-1547 x CP 63-588	1.8 $\pm$ .4	1.2-2.4*	16.7 $\pm$ 2.2	13.2-19.6*	13.4 $\pm$ 3.5	9.5-15.4*	80 $\pm$ 8.0	65-90*	90 $\pm$ 5.6	59-125*
CP 70-1547 x CP 69-1052	1.8 $\pm$ .2	1.3-2.2*	16.3 $\pm$ 2.4	13.0-19.4*	12.7 $\pm$ 3.1	9.1-15.4*	78 $\pm$ 12.5	64-86	84 $\pm$ 7.5	53-115*
CP 70-1547 x CP 70-1133	2.0 $\pm$ .5	1.5-2.9*	16.8 $\pm$ 1.4	15.1-18.5	13.6 $\pm$ 3.0	11.1 $\pm$ 16.8*	81 $\pm$ 10.1	74-90*	92 $\pm$ 6.9	70-119*
CP 71-1442 x CP 63-588	2.1 $\pm$ .4	1.9-2.3*	17.9 $\pm$ .6	17.6-18.3*	15.9 $\pm$ .7	15.7-16.1*	80 $\pm$ 2.6	76-85	112 $\pm$ 3.2	111-113*
CP 71-1442 x CP 70-1133	1.7 $\pm$ .4	1.5-1.8	15.9 $\pm$ .7	15.4-17.2	12.7 $\pm$ 1.6	11.4-14.4	79 $\pm$ 4.6	73-83	85 $\pm$ 3.5	72-98

\* = Some clones exceeding the ranges of either parent.

The percent frequency distribution for stalk weight, Brix, % sucrose, and S/T of both selected and total clones of Stage II are shown in Figure 1. The results showed that means for both stalk weight and juice quality of the selected clones were moved toward higher values under selection pressure. The clones in Stage II had mean values of 1.87, 17.35, 13.81 and 89.88 for stalk weight, Brix, % sucrose and S/T, respectively, whereas the clones selected for advancement to Stage III had mean values of 2.02, 18.54, 15.87 and 108.43, for the same characters. The frequency distribution of the total population of Stage II appeared to be fairly normal for all

four characters. The selected clones had higher means but smaller CV(%) for those four characters than did the entire population in Stage II.

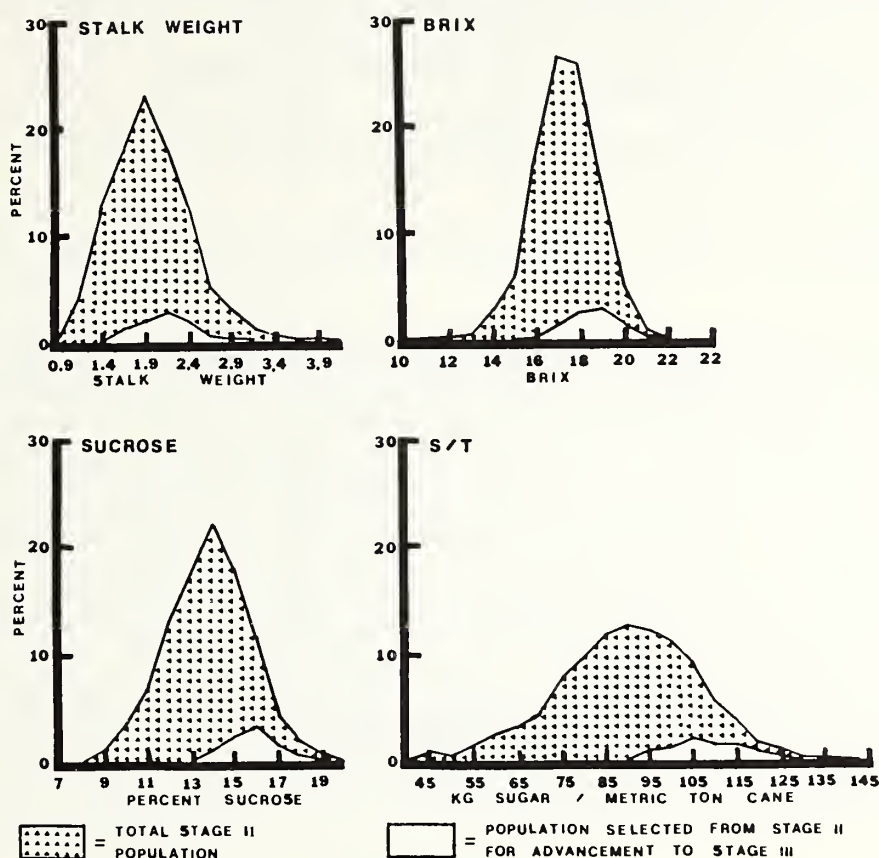


Figure 1. The percent frequency distribution for stalk weight, Brix, percent sucrose, and S/T of both selected and total clones of Stage II.

The evaluation of both parental and progeny performances indicated that the selection rate was strongly dependent on parentage and cross combination. Most of the commercial varieties used as parental clones belong to the complex hybrids of *Saccharum* spp. Clones that produce a high frequency of transgressive recombination for many agronomic traits in various crosses are highly desirable.

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## YIELD EFFECTS OF SUGARCANE SMUT INFECTION IN FLORIDA

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### ABSTRACT

Sugarcane smut, *Ustilago scitaminea* H. Syd., has been an important disease in Florida and many other regions where sugarcane is grown. The primary objective of this study was to quantify yield losses due to smut under field conditions in Florida from the plant-cane through the second-ratoon crop. An additional objective was to compare the yields of four cultivars, CP 72-1210, CP 73-1547, CP 75-1091, and CP 57-603. These cultivars were chosen to represent smut susceptibilities of resistant, moderately susceptible, susceptible, and highly susceptible, respectively. To obtain different smut levels within each cultivar, seed pieces were either treated with hot water and fungicide or inoculated by immersion in a suspension of viable smut teliospores. Smut levels were quantified by counting whips (sori) and by removing whips and weighing them. There was less variability when determining yield losses by number of whips rather than by whip mass. Actual levels of smut produced were not as expected for all treatments. Both cane and sugar yields were reduced linearly by increased smut incidence. Removing smut whips from infected plants in May and June of each growing season did not alter the effects of the disease on final yield characteristics. The highest infection level attained, 6,265 whips ha<sup>-1</sup>, reduced sugar yields by 3.85 metric tons ha<sup>-1</sup>. When quantified by mass, the highest infection level of 1.15 kg ha<sup>-1</sup> caused a sugar yield reduction of 2.69 metric tons ha<sup>-1</sup>. This experiment was conducted on a "warm-land" sugarcane location (land close to the moderating temperature effects of Lake Okeechobee) in Florida. In addition, all 3 harvests (plant-cane through second-ratoon) were late in the harvest season (February or March). Under these conditions, CP 72-1210 had significantly higher sugar yields than all other cultivars, regardless of smut treatment.

### INTRODUCTION

Sugarcane smut, *Ustilago scitaminea* H. Syd., was first reported in Florida in 1978 by Todd (10). Soon after the arrival of smut in Florida, several commercial cultivars were phased out of production due to their high susceptibility. Since that time, Florida sugarcane breeders have incorporated successful strategies in their breeding programs to select cultivars resistant to smut. The high levels of resistance of current commercial cultivars have now relegated sugarcane smut to a minor problem in Florida.

Initial reports by Holder (4) of cane yield losses of 32% from smut infection levels of 50-60% infected stools provided a sound rationale for rigorous selection strategies. In subsequent reports, Glaz et al. (3) and Irey (6) reported that yield losses were considerably less than those reported by Holder. In these reports, except for one commercial cultivar studied by Irey, yield losses of highly susceptible noncommercial cultivars were reported. In other sugarcane producing regions, Olufolaji (7) in Nigeria and Hoy et al. (5) in Louisiana reported that yield losses due to smut were similar to those reported by Holder (4). The major objective of this study was to determine the effects of sugarcane smut on sugar concentration, cane yield, and sugar yield during a three-crop cycle for four important sugarcane cultivars. In addition, this study was designed to compare the reaction to hot-water treatment of seed pieces, the production capabilities, and the effects of roguing of smut whips from infected stalks among the four cultivars.

### MATERIALS AND METHODS

The experiment was planted 23-24 Sept. 1982 at Rutledge Farms on a Florida organic soil classified as Torrey muck by Snyder et al. (8). Due to poor germination on plots where seed pieces of two cultivars, 'CP 57-603' and 'CP 75-1091', were hot-water treated, the skips in these plots were replanted on 18 Jan. 1982. The

experiment was harvested three times: the plant-cane crop was harvested 18 Feb. 1984, the first-ratoon crop was harvested 12-13 Feb. 1985, and the second-ratoon crop was harvested 4 March 1986.

The experiment was planted in a split-plot arrangement of a randomized-complete block design with four replications. Main plots were cultivars and sub plots were disease treatments. The four cultivars and their expected smut susceptibilities were 'CP 72-1210'--resistant, 'CP 73-1547'--moderately susceptible, 'CP 75-1091'--susceptible, and 'CP 57-603'--highly susceptible. The three disease treatments were hot-water and fungicide treatments of seed pieces, smut inoculation of seed pieces, and smut inoculation of seed pieces with subsequent roguing of smut whips (sori) from infected plants. The hot-water treatment was accomplished by immersing seed pieces in water maintained at 52° C with 500 ppm difolatan<sup>1</sup> for 45 minutes. Smut inoculation was accomplished by immersing seed pieces for 10 minutes in 284 liters of water at ambient temperature mixed with smut teliospores from 125 smut whips. Seed pieces in both hot-water and inoculated treatments were 44 cm in length. In obtaining seed pieces, the lower three buds from each full length stalk were discarded. All cane was planted within 2 hr of having received hot-water or inoculation treatments. Smut whips were rogued twice (May and July) per crop in the plots that received the roguing treatment. The whips that were rogued were collected in paper bags, dried, and weighed. Smut whips in all plots were counted from May through July of each crop season. Whips were marked with a ribbon at each counting to avoid counting them a second time.

Plots were four rows wide and 9.1 m long. Row and alley spaces were 1.5 m. There were no border rows between plots although there were border rows around the edges of the experiment. Stalks were counted in all rows of all plots on 14 July 1983 in the plant-cane crop, 24 and 31 May 1984 in the first-ratoon crop, and 26 August 1985 in the second-ratoon crop. The cane was cut by hand and weighed with a tractor-mounted weighing device at each harvest to determine cane yield (CY) measured as metric tons cane ha<sup>-1</sup>. Ten full length, non damaged stalks were randomly selected from each plot for milling and crusher juice analysis. All values of sugar concentration (SC) were theoretically calculated from the Brix and polarity of these samples using Arceneaux's (1) modification of the Winter-Carp-Geerligs formula and were reported as kg sugar per metric ton of cane. Sugar yield (SY) was measured as metric tons of sugar ha<sup>-1</sup> and was equal to CY x SC/1000.

All data were analyzed by analysis of variance as a split plot in time and space as described by Steel and Torrie (9). For the ratoon-crop data of CP 57-603 and CP 75-1091, SC, CY, and SY were regressed on number of whips ha<sup>-1</sup> and on weight of whips ha<sup>-1</sup>.

## RESULTS AND DISCUSSION

Heavy rains, beginning within 1 hr after the experiment was planted, kept the field flooded for the next 7 days. Subsequently, there were large, unexpected differences in germination due to treatment. The seed pieces of CP 75-1091 and CP 57-603 that had been treated with hot water germinated poorly. These plots were replanted. However, the material that was replanted germinated at levels that were similar to those of the original planting. Thus, stalk counts were low for these treatments (Table 1). The field was not excessively wet when the two cultivars were replanted. Therefore, it was probably the hot-water treatment rather than the flooding that caused the poor germination in CP 75-1091 and CP 57-603.

The original intent of this experiment was to grow four cultivars varying in smut susceptibility from resistant to highly susceptible and to further subdivide levels of smut infection (particularly in the plant-cane crop) by treating seed pieces with hot water (to reduce smut incidence) and inoculating seed pieces with smut teliospores (to increase smut incidence). Although the experiment was planted in an area known to have a high natural incidence of smut, there was no smut present on any treatments in the plant-cane crop. Smut was present in the ratoon crops, but its levels did not correspond as expected to the hot-water and inoculation treatments (Table 2). Also, CP 72-1210 and CP 73-1547 had no smut throughout the 3-year study. Thus the smut yield-loss estimates discussed here are based only on first- and second-ratoon data of CP 75-1091 and CP 57-603.

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<sup>1</sup>Mention of trade name or proprietary product does not imply or constitute endorsement or recommendation by the USDA.

Table 1. Stalk counts of four cultivars subjected to three smut treatments from the plant-cane through the second-ratoon crop.

Cultivar	Crop <sup>1</sup>	Hot-water treated	Inoculated	Inoculated and rogued	Mean
-----# stalks per ha x 1000-----					
CP 72-1210	PC	98.8	102.2	108.1	103.0
CP 73-1547	PC	89.4	90.6	93.3	91.1
CP 75-1091	PC	67.4	99.1	96.8	87.8
CP 57-603	PC	39.9	79.1	77.8	65.6
CP 72-1210	1R	103.7	133.4	145.6	127.6
CP 73-1547	1R	102.1	83.2	96.3	93.9
CP 75-1091	1R	67.6	120.5	94.4	94.2
CP 57-603	1R	45.9	66.5	72.4	61.6
CP 72-1210	2R	99.1	93.5	95.8	96.1
CP 73-1547	2R	92.7	97.0	99.3	96.3
CP 75-1091	2R	97.1	95.5	97.6	96.7
CP 57-603	2R	87.1	101.7	95.2	94.7
Mean		82.6	96.9	97.7	92.4
df					
Error a <sup>2</sup>		9	58.5		
Error b		18	108.5		
Error c		24	572.0		
Error d		48	369.5		

<sup>1</sup> PC = plant cane, 1R = first ratoon, 2R = second ratoon

<sup>2</sup> Errors a - d correspond to the errors a - d described by Steel and Torrie (9).

Table 2. Smut levels in hot-water treated and inoculated CP 57-603 and CP 75-1091.

Cultivar	Crop	Hot-water treated	Inoculated	Inoculated and rogued	Mean
----- whips per ha -----					
CP 75-1091	First ratoon	1,613	941	672	1,075
CP 57-603	First ratoon	3,047	582	2,554	2,061
CP 75-1091	Second ratoon	1,075	3,137	1,568	1,927
CP 57-603	Second ratoon	2,554	672	2,017	1,748
Mean		2,072	1,333	1,703	1,703

Most of the attention of this study was devoted to the effects of the various treatments on sugar concentration (SC), cane yield (CY), and sugar yield (SY). Yield loss estimates are reported in relation to number of smut whips ha<sup>-1</sup>. Yield losses were also calculated in relation to weight of smut whips ha<sup>-1</sup>, but these



estimates are not reported because they were similar to but not as precise as those in relation to number of whips ha<sup>-1</sup>.

**Sugar Concentration.** The disease treatments had little to no effect on SC as indicated by their low F values (Table 3). However, Comparison 19 of Table 3 indicates that in the plant-cane crop, CP 72-1210 treated with hot water had a lower SC than inoculated CP 72-1210, whereas these results were opposite with CP 75-1091. The treatment effects reversed in the second-ratoon crop when hot-water treatment gave a higher SC for CP 72-1210 and smut inoculation resulted in a higher SC for CP 75-1091 (Table 4). CP 72-1210 had no smut throughout the study so these treatment effects on it cannot be explained as effects of smut. However, for CP 75-1091, the level of smut was considerably lower in the hot-water treated as opposed to the inoculated plots in the second-ratoon crop (Table 2). Perhaps the increased smut incidence in the inoculated CP 75-1091 in second ratoon caused the increase in SC although this effect was not repeated in other comparisons.

Table 3. F values and their levels of probability for sugar concentration, cane yield, and sugar yield single degree of freedom comparisons.

Comparison	No.	Sugar Concentration			Cane yield			Sugar yield		
		F	Prob	< F	F	Prob	< F	F	Prob	< F
CP 72-1210 vs CP 57-603 (A1)	1	97.8		<0.01	41.8	0.01		80.2		<0.01
CP 72-1210 vs CP 75-1091 (A2)	2	105.5		<0.01	0.6	NS		21.2		<0.01
CP 72-1210 vs CP 73-1547 (A3)	3	86.1		<0.01	0.9	NS		10.2		<0.01
Crop linear (c)	4	179.4		<0.01	1,123.7	<0.01		24.4		<0.01
Crop quadratic	5	213.2		<0.01	99.3	<0.01		0.9		NS
A1 x C	6	0.7		NS	0.2	NS		7.7		<0.01
A2 x C	7	0.0		NS	1.7	0.20		0.9		NS
A3 x C	8	0.3		NS	6.2	0.02		0.0		NS
H vs (I + IR)/2 (B1) <sup>1</sup>	9	0.7		NS	29.1	<0.01		13.2		<0.01
I vs IR (B2)	10	1.0		NS	1.4	0.24		0.0		NS
A1 x B1	11	1.2		0.28	12.1	<0.01		6.0		0.02
A2 x B1	12	0.1		NS	7.7	0.01		4.4		0.04
A3 x B1	13	0.0		NS	0.3	NS		0.0		NS
A1 x B2	14	2.4		0.13	0.2	NS		1.9		0.18
A2 x B2	15	1.5		0.23	0.4	NS		1.6		0.22
C x B1	16	0.0		NS	80.2	<0.01		14.8		<0.01
C x B2	17	1.3		0.26	2.0	0.16		0.5		NS
A1 x C x B1	18	0.4		NS	8.1	0.01		0.5		NS
A2 x C x B1	19	4.1		0.05	0.2	NS		1.3		0.25
A3 x C x B1	20	2.6		0.11	8.5	0.01		8.7		<0.01
A1 x C x B2	21	0.1		NS	0.2	NS		0.6		NS
A2 x C x B2	22	0.2		NS	0.7	NS		0.2		NS
df										
Error a <sup>2</sup>	9		77.5			289.5			7.4	
Error b	18		71.6			84.0			2.7	
Error c	24		74.2			241.4			4.0	
Error d	48		122.4			76.1			2.9	
CV (%)			10.1			7.5			13.2	

<sup>1</sup> H = hot-water treated seed pieces, I = seed pieces inoculated with smut, IR = seed pieces inoculated with smut and subsequently rogued.

<sup>2</sup> Errors a, b, c, and d are reps x cultivars, reps x cultivars x crop, reps within cultivars x crop, and reps within cultivars x disease treatment x crop, respectively.



The linear and quadratic regressions of SC on number of whips ha<sup>-1</sup> were not significant.

There were some important SC differences due to effects not related to disease treatments. CP 72-1210 had a significantly higher SC than the other three cultivars in all three crops (Comparisons 1-3 and 6-8 Table 3, and Table 4). When only the effect of crop was considered, SC increased significantly from the plant-cane crop to the first-ratoon crop and then dropped significantly in the second-ratoon crop (Comparison 5 Table 3, and Table 4). The low SC in the second-ratoon crop was probably due to below freezing temperatures that occurred shortly before the second-ratoon harvest.

Table 4. Sugar concentrations of four cultivars subjected to three smut treatments from the plant-cane through the second-ratoon crop.

Cultivar	Crop <sup>1</sup>	Hot-water treated	Inoculated	Inoculated and rogued	Mean
-----kg sugar per metric ton cane-----					
CP 72-1210	PC	124.5	133.1	133.8	130.5
CP 72-1547	PC	110.8	117.0	100.7	109.5
CP 75-1091	PC	111.5	108.6	106.7	108.9
CP 57-603	PC	107.7	114.2	101.0	107.6
CP 72-1210	1R	140.5	135.8	142.0	139.4
CP 73-1547	1R	120.2	119.7	122.3	120.7
CP 75-1091	1R	118.4	118.5	117.9	118.3
CP 57-603	1R	123.4	118.3	116.1	119.3
CP 72-1210	2R	109.8	102.6	104.1	105.5
CP 73-1547	2R	84.3	84.6	93.2	87.4
CP 75-1091	2R	78.7	90.8	83.3	84.3
CP 57-603	2R	91.3	84.2	85.1	86.9
Mean		110.1	110.6	108.8	109.8

<sup>1</sup> PC - plant cane, 1R = first ratoon, 2R = second ratoon.

**Cane Yield.** Overall, the cane treated with hot water had a significantly lower CY than the cane that was inoculated with smut (Comparison 9 Table 3, and Table 5). However, there were many significant interactions of disease treatment with cultivar and crop. For comparisons of disease treatment and CP 72-1210 with CP 57-603 or CP 73-1547, there were significant interactions with crop (Comparisons 18 and 20 Table 3). CP 72-1210 had a reduced CY in the plant-cane crop, but increased CY's in the ratoon crops due to hot-water treatment of seed pieces (Table 5). Since hot-water treated plots of CP 72-1210 had reduced stalk counts in both the plant-cane and first-ratoon crops, the major cause of the CY differences was probably something other than the reduced germination caused by the hot-water treatment (Table 1). Hot-water treatment caused reduced CY's in the plant-cane and first-ratoon crops and no change in CY compared to smut inoculated cane in the second-ratoon crop for CP 57-603 (Table 5). Since the hot-water treated and inoculated plots of CP 57-603 had similar relative smut incidence in the two ratoon crops, the relative improvement in the CY production of the CP 57-603 hot-water treated plots in second ratoon was not due to decreased incidence of smut. In this case, most of the yield differences among crops was probably related to the reduced germination caused by hot-water treatment of CP 57-603 (Table 1). In the first two crops when effects of hot-water treatment on number of harvestable stalks were highest, the CY's of the hot-water treated plots were lower than those of the inoculated plots. However, by second ratoon when the number of harvestable stalks was similar for both treatments, the CY's were no longer significantly different (Table 1 and Table 5).

Table 5. Cane yields of four cultivars subjected to three smut treatments from the plant-cane through the second-ratoon crop.

Cultivar	Crop <sup>1</sup>	Hot-water treated	Inoculated	Inoculated and rogued	Mean
----- metric tons per ha-----					
CP 72-1210	PC	146.5	154.2	163.8	154.8
CP 73-1547	PC	168.7	168.4	171.5	169.5
CP 75-1091	PC	129.0	171.1	167.5	155.9
CP 57-603	PC	92.9	142.2	151.9	129.0
CP 72-1210	1R	120.1	112.7	118.0	116.9
CP 73-1547	1R	113.3	110.3	110.1	111.2
CP 75-1091	1R	105.7	112.8	117.9	112.1
CP 57-603	1R	63.3	87.3	86.2	78.9
CP 72-1210	2R	103.1	91.3	93.9	96.1
CP 73-1547	2R	92.4	104.6	99.0	98.7
CP 75-1091	2R	82.7	94.9	94.4	90.7
CP 57-603	2R	72.4	74.6	71.9	73.0
Mean		107.5	118.7	120.5	115.6

<sup>1</sup> PC = plant cane, 1R = first ratoon, 2R = second ratoon.

Hot-water treatment had no effect on the CY's of CP 73-1547 in the first two crops, but it did cause a small decline in CY in the second-ratoon crop (Table 5). Since there was no smut in any CP 73-1547 treatments, and stalk numbers were not affected by disease treatments with CP 73-1547 (Table 1), it is difficult to explain the cause of this yield loss in the second-ratoon crop. These summaries assumed that lower levels of CY's for hot-water compared to smut inoculated treatments were due to hot-water treatment having caused reduced CY's rather than smut inoculation having caused increased CY's. We know of no evidence that smut inoculation increases CY, but Benda (2) has demonstrated that hot-water treatment of seed pieces can reduce germination in some cultivars.

Linear regression provided the best fitting estimate of CY decline due to increasing incidence of smut infection (Fig. 1). As were the  $r^2$  values reported previously by Glaz et al. (3) and Irely (6), the  $r^2$  value of this regression was significant but low. Thus, the 95% confidence intervals of means have also been included in Fig. 1. We can be 95% certain that at any level of smut from 0 to 6000 whips ha<sup>-1</sup>, the mean CY will be within the corresponding interval shown. The equation shows that for every 1000 whips ha<sup>-1</sup>, CY declined by 4.81 metric tons ha<sup>-1</sup>. In previous studies, Glaz et al. (3) and Irely (6) reported CY losses of 2.3 and 4.1%, respectively, with 10% infected stalks. In Nigeria, Olufolaji (7) and in Louisiana, Hoy et al. (5) reported losses in CY of 6 to 10% at 10% smut infection levels. Assuming stalk populations of 61,000 ha<sup>-1</sup>, the present study predicts CY declines of about 30% with 10% infected stalks. One factor that may have caused the yield losses related to smut to be higher than expected was the reduced stalk counts in the hot-water treated CP 57-603 and CP 75-1091 plots. However, these stalk counts were only reduced in the plant-cane and first-ratoon crops (Table 1). Since the regressions describing smut were only calculated from first- and second-ratoon data, it is not expected that the stalk count factor accounted for the large magnitude of difference between this and other studies.

The logical conclusion of the previous information is that under some environmental conditions, smut may cause more yield losses than previously suspected. However, the present study also presented results that conflict with this conclusion. The plots of CP 57-603 that were inoculated and rogued had higher smut levels than the CP 57-603 plots that were inoculated (Table 2). However, these increased smut levels did not cause

a decline in CY (Tables 3 and 5). The most prudent overall conclusion is that since there has been success in selecting smut resistant clones in Florida, this overall strategy should be continued.

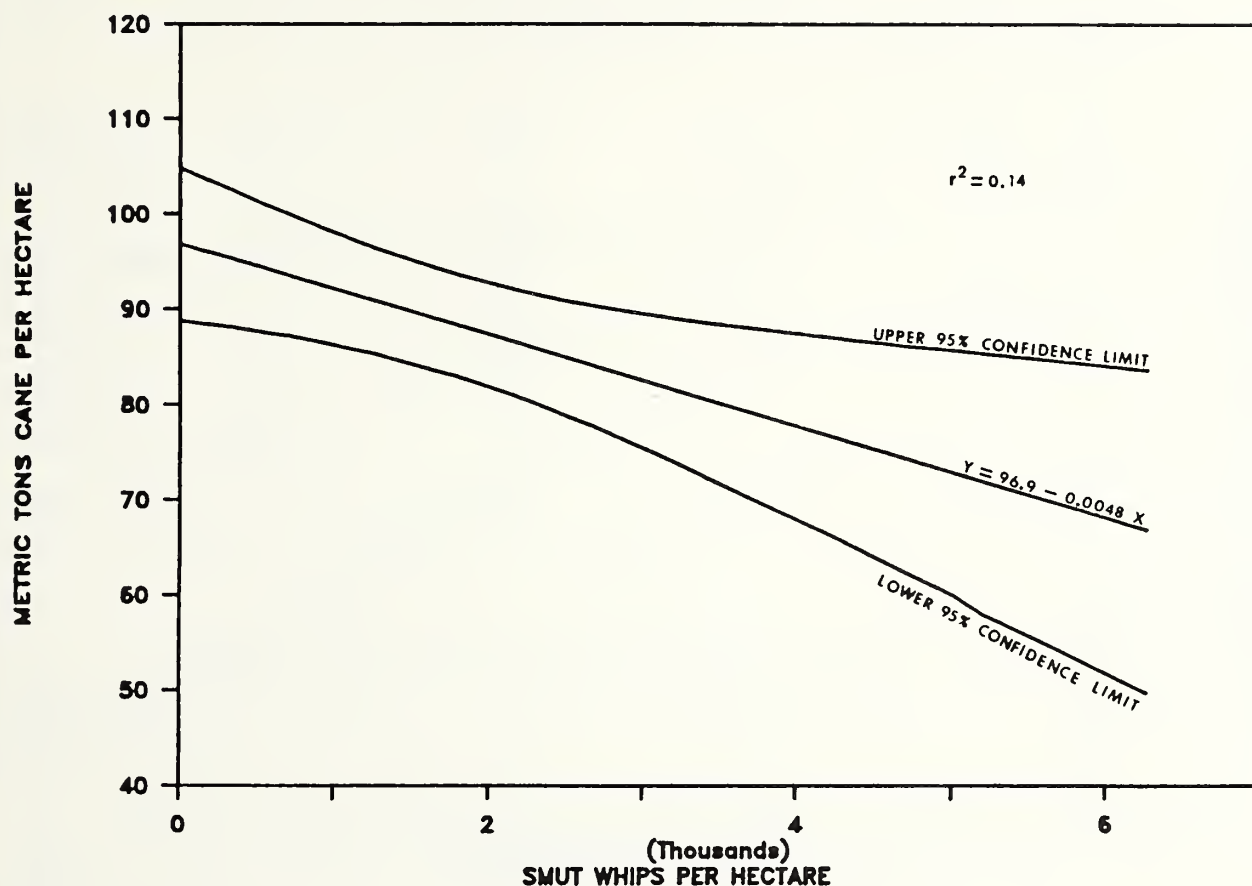


Figure 1. Linear regression and 95% confidence limits of means of metric tons of cane per hectare on number of smut whips per hectare.

Sugar Yield. As with CY, hot-water treatment of seed pieces caused a significant reduction in SY (Comparison 9 Table 3), and as with CY, this effect was not similar for all cultivars (Comparisons 11-13 Table 3). Hot-water treatment had no effect on the SY's of CP 72-1210 or CP 73-1547, whereas hot-water treatment caused significant reductions in SY of CP 75-1091 and CP 57-603 (Table 6). For both cultivars with reduced SY's, the cause was probably the lower germination after hot-water treatment (Table 1). For CP 57-603 a second probable cause was the increased smut incidence in the plots that were treated with hot water (Table 2). As with CY, linear regression provided the best fit to describe SY decline with increasing smut incidence (Fig.2). Sugar yield declined by 0.62 metric tons  $ha^{-1}$  with every increase of 1000 smut whips  $ha^{-1}$ .

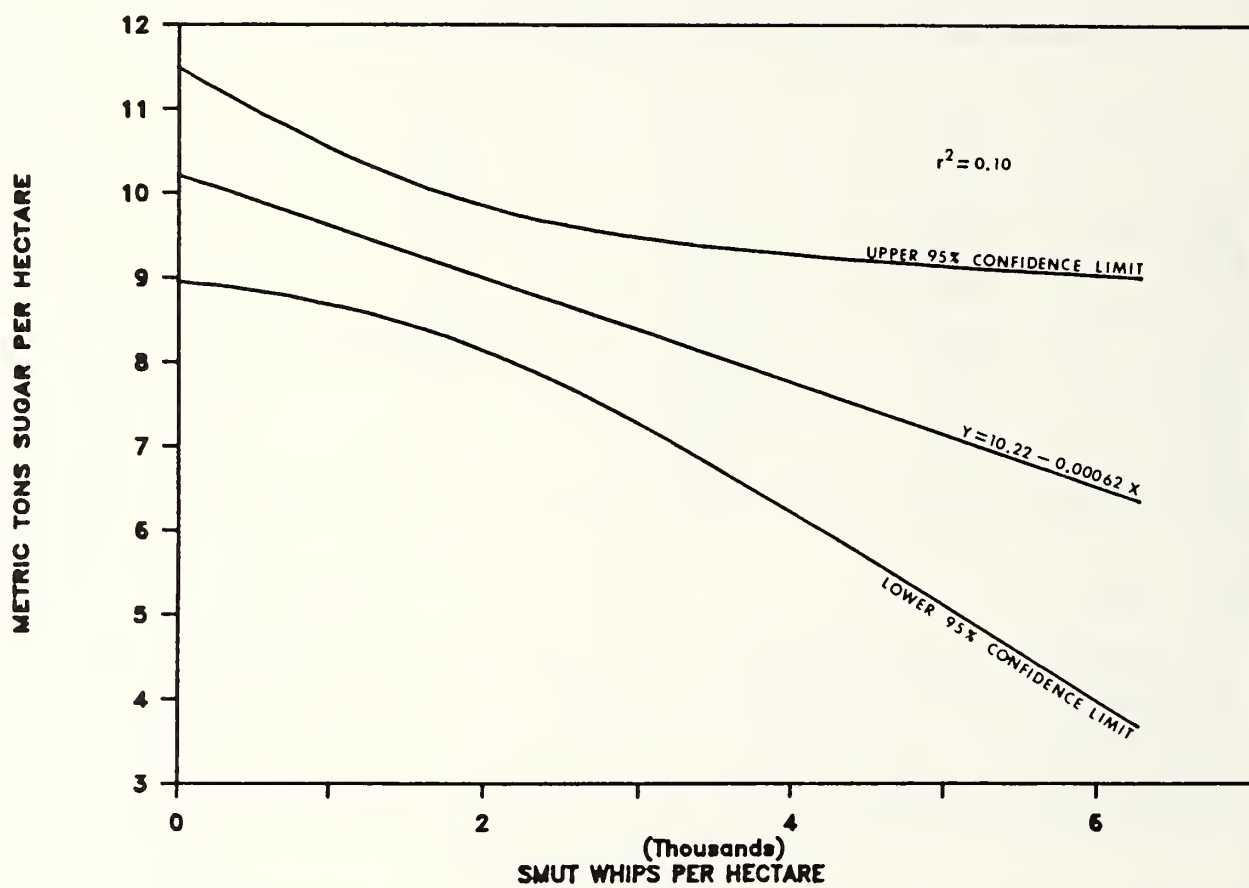


Figure 2. Linear regression and 95% confidence limits of means of metric tons of sugar per hectare on number of smut whips per hectare.



Table 6. Sugar yields of four cultivars subjected to three smut treatments from the plant-cane through the second-ratoon crop.

Cultivar	Crop <sup>1</sup>	Hot-water treated	Inoculated	Inoculated and rogued	Mean
----- metric tons per ha-----					
CP 72-1210	PC	18.3	20.5	22.0	20.3
CP 73-1547	PC	18.8	19.7	17.3	18.6
CP 75-1091	PC	14.4	18.6	17.9	17.0
CP 57-603	PC	10.1	16.2	15.2	13.8
CP 72-1210	1R	16.9	15.3	16.7	16.3
CP 73-1547	1R	13.6	13.2	13.4	13.4
CP 75-1091	1R	12.5	13.7	13.9	13.4
CP 57-603	1R	7.8	10.3	10.0	9.4
CP 72-1210	2R	11.3	9.4	9.7	10.1
CP 73-1547	2R	7.7	8.8	9.1	8.5
CP 75-1091	2R	6.6	8.7	7.9	7.7
CP 57-603	2R	6.6	6.3	6.1	6.3
Mean		12.1	13.4	13.3	12.9

<sup>1</sup> PC = plant cane, 1 R = first ratoon, 2R = second ratoon.

In treatment comparisons not related directly to disease treatments, the cultivar with the highest SY across all treatments was CP 72-1210 (Comparisons 1-3 Table 3, and Table 6). Overall, SY declined linearly (Comparison 4 Table 3) from 17.4 metric tons ha<sup>-1</sup> in the plant-cane crop to 8.2 metric tons ha<sup>-1</sup> in the second-ratoon crop.

There were no significant differences between inoculated cane that was rogued and not rogued for SC, CY, or SY (Comparison 10 Table 3). Also, there were no significant interactions of this comparison with cultivars or crops (Comparisons 14-17 and 21-22 Table 3). Therefore, roguing did not affect SC, CY, or SY, neither in the year in which the cane was rogued, nor in the second-ratoon crop after having been rogued in the first-ratoon crop.

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## NUTRITIONAL STATUS SURVEY OF SUGARCANE IN TEXAS<sup>1</sup>

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### ABSTRACT

Nutrient imbalance may contribute to the low average sugarcane tonnage in the Lower Rio Grande Valley (LRGV). A survey was conducted to determine the extent of reported K deficiency and to evaluate the nutrient status of sugarcane in the LRGV. The diagnostic recommendation integrated system (DRIS) and critical nutrient levels were used to diagnose the nutrient status of the sugarcane fields. Based on critical levels, N was the primary nutrient limiting cane growth. Nitrogen was deficient in 38% of the 3-month-old cane surveyed. Phosphorous and potassium deficiencies were found in 11 and 8% of the fields, respectively. Low leaf P and K levels may reflect the effects of soil moisture and N on P and K availability and uptake. Adjustment of the low leaf P and K concentrations for the effects of N raised the P and K values into their normal range. DRIS analysis suggested that 34% of the 3-month-old cane surveyed required K to achieve nutrient balance. Nitrogen and phosphorous were required in 49 and 14% of the surveyed fields, respectively.

### INTRODUCTION

The low average per acre sugarcane tonnage in the Lower Rio Grande Valley (LRGV) may be associated with nutritional disorders. Nitrogen (N) and iron deficiencies in ratoon crops have occurred on all cultivars and soil types (11, 12, 15). Deficiency symptoms for phosphorous (P) has not been observed, but leaf P concentrations of some cane fields were near the critical level. However, no yield response to P fertilizer has been obtained (16). Leaf K concentrations below the critical level have been reported (16). However, potassium (K), calcium (Ca), and magnesium (Mg) levels in LRGV soils are believed to be adequate for full growth. Hipp (8) reported that clay minerals in the LRGV soils had a large capacity to supply K to plants and to replenish the soil K used by plants.

It is generally recognized that plant growth depends on the concentration or intensity of different essential nutrients above a critical level and on the balances between them. Foliar analysis is used in many sugarcane growing areas to diagnose possible nutrient deficiencies and imbalances (1, 5, 6). In this study, the nutrient composition of leaves from low and high yielding sugarcane fields were monitored throughout the growing seasons to determine the extent of a possible K deficiency and to evaluate the nutrient status of sugarcane in the LRGV. The relationships between nutrient concentration, nutrient ratios, cane yield and sugar content were evaluated.

### MATERIALS AND METHODS

Critical nutrient levels (6) and ratios established in other areas and confirmed or modified by fertilizer studies in LRGV were used to diagnose the nutrient status of the sugarcane fields. Nitrogen sufficiency curves (14) for cultivars NCo 310, CP 52-68, and CP 65-357 suggested that leaf N levels for 3-month-old cane should be 2.18, 2.10, and 2.00%, respectively. Corresponding levels for 6-month-old cane were 1.68, 1.73, and 1.66%. Normal concentrations from the literature (6) and used for all cane ages were P (0.24 to 0.18%), K (1.35 to 1.02%), Ca (0.16-0.20%) and Mg (0.08-0.19%). As N may affect the uptake of P and K, the leaf concentrations of P and K were adjusted for N (X) by the relationships:

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<sup>1</sup>Contribution of the Conservation and Production Systems Research Unit, ARS, USDA, Weslaco, TX in cooperation with Rio Grande Valley Sugar Growers, Inc., Santa Rosa, TX

$$\text{adj } P_N = P + 0.1172 (X - x) \text{ and}$$

$$\text{adj } K_N = K + 0.545 (X - x)$$

where  $x$  is the normal leaf N concentrations at a given age. The Diagnosis and Recommendations Integrated System (DRIS) was used to evaluate the balance among the various nutrients (1, 2). DRIS diagnostic norms established for sugarcane in Florida and South Africa were based on the mineral compositions of the top visible dewlap (TVD) leaf laminae. However, nutrient norms established for the TVD leaves may not apply when other leaves are selected. In this study the normal nutrient ratios were based on the mineral composition of leaves 3 through 6, counting the spindle leaf as No. 1, from cane 3 to 6 months of age. The leaves were collected from sugarcane that produced more than 45 tons/acre. The Texas norms are slightly different from the norms used in Florida (Table 1). Correlations between the N, P and K concentration of the TVD and the 3 through 6 leaves were highly significant. The coefficient of determination ( $r^2 \times 100$ ) were 85, 89 and 84%, respectively, for N, P and K. The DRIS diagnostic norms were assumed to be constant throughout the growing season (10).

Table 1. Normal nutritional ratios used.

Ratio	Number	Texas <sup>1</sup>			Florida <sup>2</sup>		
		Mean Value	SD	CV	Mean Value	SD	CV
N/P	733	9.68	1.441	14.9	8.71	1.199	13.8
N/K	305	1.42	0.297	20.9	1.53	0.257	16.8
K/P	288	7.04	1.852	26.1	5.63	1.038	18.4
Ca/N	295	0.20	0.049	25.2	0.15	0.032	21.3
Ca/P	285	1.87	0.572	30.6	1.31	0.349	26.6
Ca/K	296	0.28	0.099	35.0	0.22	0.063	28.4
Mg/N	308	0.10	0.025	25.5	0.11	0.028	24.5
Mg/P	298	0.92	0.275	30.0	0.98	0.284	28.9
Mg/K	305	0.14	0.049	35.6	0.16	0.052	32.1
Ca/Mg	262	1.91	0.728	38.1	1.37	0.381	27.8
N/H <sub>2</sub> O	910	0.02	0.003	13.6			
H <sub>2</sub> O <sup>2</sup> /P	721	452.00	78.380	17.3			

<sup>1</sup> 3 through 6-month-old cane, leaves no. 3 through 6.

<sup>2</sup> TVD leaf (6).

The availability of soil water is a major yield-determining factor not explicitly evaluated in the DRIS diagnosis. The effects of moisture stress on the plants nutrient composition were minimized by collecting leaf samples within a few days of an irrigation or rainfall event. However, as the N, P and K concentrations were significantly related to the plant's moisture status, the DRIS approach was modified to evaluate the nutrient-moisture relationship. Normal nutrient-moisture ratios between leaf N or P concentrations and the leaf sheath moisture (M) levels were established. The leaves and sheaths were collected from N fertilized and irrigated sugarcane that produced more than 45 tons/acre. The normal N/M and M/P ratios were the means of 910 and 721 ratios, respectively.

Since sheath moisture changed throughout the growing season, the relation:  $\% M = 86.95 - 0.26X$ ,  $r = 0.89$ , between sheath moisture (M) and cane age (X) expressed in terms of climatological weeks was used to calculate the normal sheath moisture level for a given age. March 1-7, inclusive, is climatological week number one and closely approximates the dates of growth initiation. In week 12 (3-month-old cane) the normal sheath moisture level was 83.8%. Corresponding values for 4 and 6-month-old cane were 82.7 and 81.7%.



Thirty-seven commercial sugarcane fields were selected to represent fields with high and low production records and different soil types (Table 2). The sampled fields occupied 4.8% of the sugarcane acreage in the LRGV. Five fields contained more than one cultivar. One field had two soil types.

Table 2. Soils included in study.

Soil name	Subgroup
Brennan fine sandy loam	Aridic Haplustalfs
Camargo silty clay loam	Tupic Ustifluvents
Hargil fine sandy loam	Udic Paleustolls
Harlingen clay	Entic Chromusterts
Hidalgo sandy clay loam	Typi Calciustolls
Laredo silty clay loam	Fluventic Haplustolls
Lyford sandy clay loam	Aquic Haplustalfs
Matamoros silty clay loam	Vertic Ustifluvents
Mercedes clay	Udorthentic Pellusterts
Olmito clay loam	Vertic Calciustolls
Raymondville clay loam	Vertic Calciustolls
Willacy fine sandy loam	Udic Argiustolls

Leaves and sheaths numbered 3 through 6 (spindle leaf No. 1) were collected from five stalks at each sampling site at 3, 4 and 6 months of age. The sheaths were separated from the leaves at the dewlap and dried at 70°C for moisture determination. The middle third of the leaf blades with midribs removed were dried (70°C) ground to pass a 2 mm sieve, and analyzed for total N (4), P(3), K, Ca, and Mg by atomic absorption method. Data on sugarcane tonnage, sugar yields and juice quality were obtained from commercial field records (Cowley Sugar House). The vegetative growth index, expressed on the green sheath weight, was used as an indicator of cane growth. Correlation and regression analysis were used to evaluate the relationships between yields, cane growth, juice quality and leaf mineral composition.

Solar radiation data were obtained from measured values at the USDA laboratory in Weslaco, Texas.

## RESULTS AND DISCUSSION

Production records suggested that half of the selected fields should produce at least 45 tons of cane per acre; however, the actual yields were lower than expected. Fields with high or low yield records averaged 37.9 and 25.6 tons/acre, respectively. Freezing temperatures during January 1982 affected the plant population of the 1982-83 crop and the low average daily radiation of 381 gm cal/cm<sup>2</sup>/day during the 245 day growth period, March 1 through October 31, 1982, decreased plant growth. The average daily radiation for the previous 20 years was 456 gm cal/cm<sup>2</sup>/day for the same period. The low average daily radiation reflects the effect of volcanic ash from the El Chichon volcanic eruption (9).

Yields of cane and sugar listed by cultivar, crop cycle, and soil types are given in Table 3. Variation in yields and juice quality were high. Cane and sugar yields ranged from 11.5 to 48.7 and 0.92 to 4.93 tons/acre, respectively. Pol ranged from 9.5 to 13.3% and juice purity from 75.2 to 84.5%. The cane fields varied in cycle from plant through the 9th ratoon. Eight percent of the fields were in plant cane, 51.5% were 1st, 2nd and 3rd ratoon crops, 21.6% were 4 through 8 ratoons and 18.9% were 9th ratoon crops. No 5th ratoon crops were in the survey. Plant cane which was expected to produce the highest tonnage averaged 27.5 tons/acre whereas 1st and 2nd ratoon crop yields averaged 31.9 tons/acre. The lowest yield (0.6 tons/acre) was produced by an unfertilized and nonirrigated 9th ratoon crop of NCo 310 on Raymondville clay loam. However, on fertilized and irrigated fields, 9th ratoon crop yields averaged 27.6 tons/acre. No significant relationships were found between cane yields and cultivars, crop cycle or soil types.

Table 3. Soil type, cultivar, sugarcane cycle, yields and juice quality.

Cultivar	Cycle	Soil type	Yield		Juice Quality	
			Cane	Sugar	Pol	Purity
			(Tons/acre)		(%)	
NCO 310	3	Harlingen clay	48.7	4.93	13.3	82.6
NCO 310	8	Raymondville clay loam	44.2	4.17	12.1	82.4
NCO 310	2	Camargo silty clay	43.8	4.11	12.4	82.5
NCO 310	9	Laredo silty clay loam	42.2	4.36	12.8	83.0
NCO 310	10	Matamoros silty clay	40.2	3.60	11.4	81.5
NCO 310	4	Hidalgo sandy clay loam	35.6	2.86	11.3	76.0
NCO 310	2	Raymondville clay loam	35.3	3.08	11.8	79.3
NCO 310	2	Harlingen clay	35.1	3.19	11.9	81.7
NCO 310	1	Mercedes clay	34.7	2.55	13.2	84.5
NCO 310	2	Raymondville clay loam	34.0	3.38	12.5	82.4
NCO 310	3	Raymondville clay loam	34.0	3.18	12.0	82.4
NCO 310	10	Willacy fine sandy loam	31.1	2.13	9.5	75.2
NCO 310	7	Laredo silty clay loam	30.7	2.77	11.8	79.7
NCO 310	4	Raymondville clay loam	26.8	2.35	11.5	78.8
NCO 310	10	Hidalgo sandy clay loam	26.7	2.42	11.6	81.5
NCO 310	8	Harlingen clay	24.3	2.20	11.7	78.5
NCO 310	10	Raymondville clay loam	23.9	1.92	12.0	80.2
NCO 310	10	Hidalgo sandy clay loam	22.7	1.97	11.6	81.7
NCO 310	10	Hidalgo sandy clay loam	20.5	1.87	11.9	81.1
NCO 310	9	Harlingen clay	19.5	1.76	12.0	80.1
NCO 310	10	Raymondville clay loam	0.6	0.05	11.1	79.3
CP 65-357	3	Laredo silty clay loam	47.9	4.47	12.4	79.9
CP 65-357	3	Harlingen clay	47.6	4.36	12.0	80.4
CP 65-357	3	Hidalgo sandy clay loam	44.6	4.13	12.2	82.2
CP 65-357	5	Harlingen clay	41.0	3.44	11.3	80.4
CP 65-357	4	Willacy fine sandy loam	37.5	2.79	10.8	79.4
CP 65-357	3	Brennan fine sandy loam	35.6	2.86	11.3	76.0
CP 65-357	2	Raymondville clay loam	35.3	3.08	11.8	79.3
CP 65-357	2	Raymondville clay loam	32.6	2.79	11.3	79.6
CP 65-357	7	Laredo silty clay loam	30.7	2.77	11.8	79.7
CP 65-357	2	Raymondville clay loam	29.8	2.98	13.2	82.5
CP 65-357	7	Harlingen clay	29.1	2.78	12.8	81.4
CP 65-357	2	Raymondville clay loam	26.1	2.43	12.0	80.0
CP 65-357	2	Mercedes clay loam	26.1	2.43	12.3	80.0
CP 65-357	3	Lyford sandy clay loam	24.7	2.11	10.9	80.1
CP 65-357	1	Mercedes clay loam	24.7	2.11	10.9	80.1
CP 65-357	3	Lyford sandy clay loam	24.7	2.08	11.7	80.1
CP 65-357	4	Hidalgo sandy clay loam	14.8	1.16	10.5	78.2
CP 65-357	3	Lyford sandy clay loam	11.5	0.92	10.8	79.4
CP 70-321	1	Harlingen clay and Olmito (saline)	31.1	2.50	10.8	78.8
CP 70-321	2	Raymondville clay loam	29.8	2.98	13.2	82.5
CP 70-321	1	Raymondville clay loam	23.6	2.00	12.3	78.8
CP 70-321	8	Hargill fine sandy loam	25.3	2.12	11.4	78.3

Cycle

Plant cane 1

Ratoons 2-10

Table 4. Range and means of leaf mineral content and nutrient ratios at three cane ages.

Variable	3 months		4 months		6 months	
	Range	Mean	Range	Mean	Range	Mean
Leaf mineral %						
N	1.24- 2.57	2.03	1.18- 2.30	1.82	0.94- 1.51	1.25
P	0.17- 0.31	0.23	0.15- 0.25	0.20	0.12- 0.25	0.16
K	0.79- 1.95	1.41	0.83-2.12	1.38	0.84- 1.45	1.22
Ca	0.29- 0.76	0.46	0.20- 0.46	0.35	0.17- 0.49	0.27
Mg	0.11- 0.41	0.20	0.09- 0.24	0.15	0.08- 0.21	0.13
Cl	0.39- 0.90	0.58	0.33- 0.67	0.53	0.23- 0.62	0.48
Sheath						
Moisture %	76.7- 86.5	83.1	74.5- 85.4	81.7	71.3- 79.4	77.1
Nutrient Ratios						
N/P	6.28- 11.77	8.96	6.27- 11.90	9.01	3.86- 10.38	7.82
N/K	1.00- 2.23	1.46	0.85- 2.28	1.35	0.79- 1.25	1.03
K/P	3.51- 9.94	6.39	4.69- 11.71	6.83	4.19-10.30	7.63
Ca/N	0.12- 0.37	0.23	0.11- 0.32	0.19	0.14- 0.52	0.22
Ca/P	1.36- 3.42	2.02	0.94- 2.76	1.73	1.17- 2.48	1.67
Ca/K	0.13- 0.66	0.34	0.13- 0.51	0.27	0.13- 0.59	0.23
Mg/N	0.06- 0.17	0.10	0.06- 0.11	0.08	0.02- 0.22	0.10
Mg/P	1.85- 0.51	0.94	1.14- 0.51	0.73	1.21- 0.12	0.77
Mg/K	0.07- 0.36	0.15	0.07- 0.18	0.11	0.02- 0.25	0.10
Ca/Mg	4.17- 1.12	2.33	4.35- 1.45	2.44	2.70- 1.54	2.13
N/H <sub>2</sub> O	0.030- 0.16	0.024	0.027- 0.016	0.022	0.019- 0.013	0.016
H <sub>2</sub> O/P	451.3- 279.0	361.3	496.7- 341.6	408.5	594.2- 305.4	401.9

Cane fields in need of irrigation or fertilization were easily identified by low sheath moisture and leaf N levels. The range and means of the leaf mineral concentration and nutrient ratios are presented in Table 4. The nutrient concentration and ratios among N, P, K, Ca, and Mg in the leaf tissues changed as the cane matured. The leaf N, P, and K concentrations in the 3-month-old cane were lower than normal in 38, 11, and 8%, respectively, of the sampled fields (Table 5). However, when the leaf P and K values were adjusted for the effects of N, none of the fields were deficient in P or K. The low P and K concentrations were associated with N deficient cane. The Ca and Mg values were higher than those considered normal for adequate nutrition. Some fields were fertilized after May 3rd; this reduced the percentage of fields with N and P deficient cane. However, the leaf N concentrations in all fields of 6-month-old cane were below normal, approximately 2 months before harvest of the early cultivars.

Low sheath moisture levels probably reflected the low N status of the crops and low soil water availability. Clements (5) states that "any element in deficient supply lowers tissue moisture" and Thomas et. al. (13) found that sheath moisture was significantly affected by the irrigation regime and row spacing. Significant correlation coefficient  $r = 0.69$  and  $r = 0.70$  for 3 and 4-month-old cane, respectively, suggested that leaf N and sheath moisture were interdependent.



Growth of sugarcane, as indicated by the vegetative growth index (VGI), was significantly influenced by the N, K and moisture status of the plant. The relation between VGI (Y), leaf N and K concentration and sheath moisture (M) of 3-month-old cane is given by the regression equation.

$$Y = -192.24 - 24.93N + 16.45K + 3.10M \quad (r = 0.65).$$

The VGI is associated with stem girth (5) and is generally used to monitor the effects of soil moisture or N fertilization on cane growth.

Table 5. Evaluation of nutrient status of sugarcane in Texas based on nutritional concentrations in laminae of leaves 3, 4, 5, and 6.

Nutrient	Relative level	Cane age-months		
		3	4	6
% of fields classified				
Nitrogen	High	30	27	--
	Normal	32	27	--
	Low	38	46	100
Phosphorus	High	40	5	--
	Normal	49	76	22
	Low	11	19	78
Potassium	High	76	62	27
	Normal	16	30	68
	Low	8	8	5

Cane yields were significantly correlated (Table 6) with the moisture and N status of the crop at 3, 4, and 6 month of growth, but the degree of correlation was low. Variation in leaf N and sheath moisture levels of the 3-month-old cane accounted for 12 and 17.5%, respectively, of the yield variability. Nonsignificant partial correlation coefficients  $r_{yn,m} = 0.08$  and  $r_{ym,n} = 0.26$  show that neither N nor sheath moisture influenced yields independently of each other. Stepwise regression analysis indicated that cane yields were significantly related to the N, P, Mg and sheath moisture content of 3-month-old cane. Variation in the percentages of these three nutrients and sheaths moisture accounted for 43% of the yield variability. The relationship between yields and leaf K percentage of 6-month-old cane may reflect interaction between N and K or K and sheath moisture. However, partial correlation coefficients between yields and K at the same N level ( $r_{yk,n} = 0.43$ ) and at the same sheath moisture level ( $r_{yk,m} = 0.37$ ) were significant indicating that K influenced yields independent of N or moisture. Nonsignificant partial correlation coefficients ( $r_{nk,m} = 0.23$ ) between N and K at the same sheath moisture level implied that the N K correlation reflected the influence of moisture availability rather than N on K uptake. Figure 1 shows that sheath moisture influences the leaf K concentration.

DRIS (2) indices based on N/P, N/K and K/P ratios suggested that N, P, or K was the most required nutrient in 49, 14, and 34%, respectively, of the 3-month-old cane surveyed (Table 7). A few fields required both N and K. Whereas, DRIS indices based on ratios involving five elements implied that N, P, K, Ca or Mg were required in 25, 5, 27, 15, and 28%, respectively, of the fields to achieve nutrient balance. DRIS indices based on 10 ratios are reportedly more accurate than indices calculated from 3 ratios (7). Lack of yield responses to Mg or K (16) by sugarcane on LRGV soils prevents the determination of the accuracy of the Mg and K diagnosis.

DRIS indices range from negative to positive values depending on whether the nutrient was relatively deficient or excessive with respect to the other nutrients (2). The degree of nutritional balance decreases as the



absolute sum of the DRIS indices increases. Sumner (10) stated that the potential yield attainable increases as the sum of the DRIS indices decreases. Low yields and low sums suggests that other factors were limiting yields.

Table 6. Correlation coefficients, and probability levels relating cane yields to the nutrient content of leaves and sheath moisture.

Item correlated	3 month		4 month		6 month	
	r	p	r	p	r	p
N	0.347	0.0355	0.543	0.0005	0.378	0.0194
P	-0.133	0.4319	0.120	0.4777	-0.543	0.0004
K	0.318	0.0550	0.177	0.2945	0.499	0.0014
Sheath moisture	0.419	0.0099	0.368	0.0252	0.408	0.0109

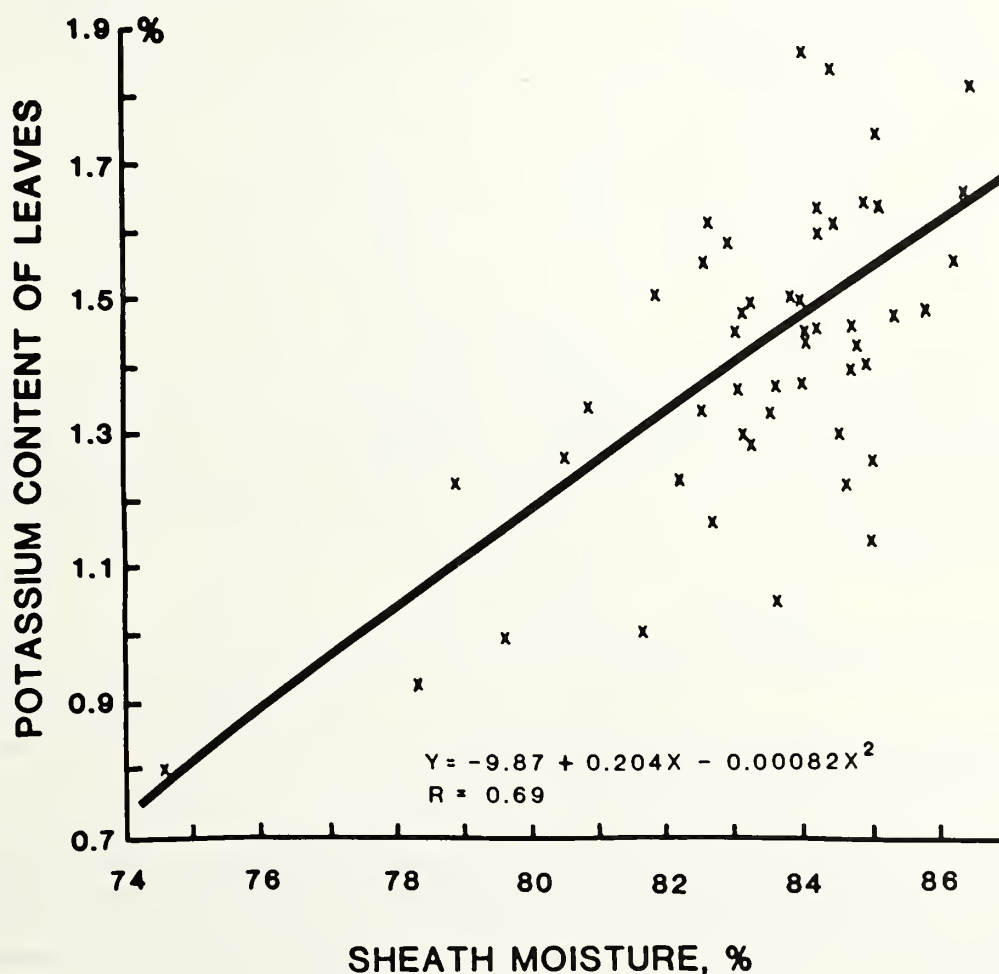


Figure 1. Relationship between leaf K concentration and sheath moisture level of 3-month-old sugarcane.

In the surveyed sugarcane the absolute values of the indices were small, less than 100 throughout the season, and were not correlated with cane yields. The average absolute values of the DRIS indices for fields with high or low yield records were 10.8 and 17.8. No significant relationships were found between cane yields and the DRIS indices for N, K, P or sheath moisture of 3 month (Figure 2) or older cane.

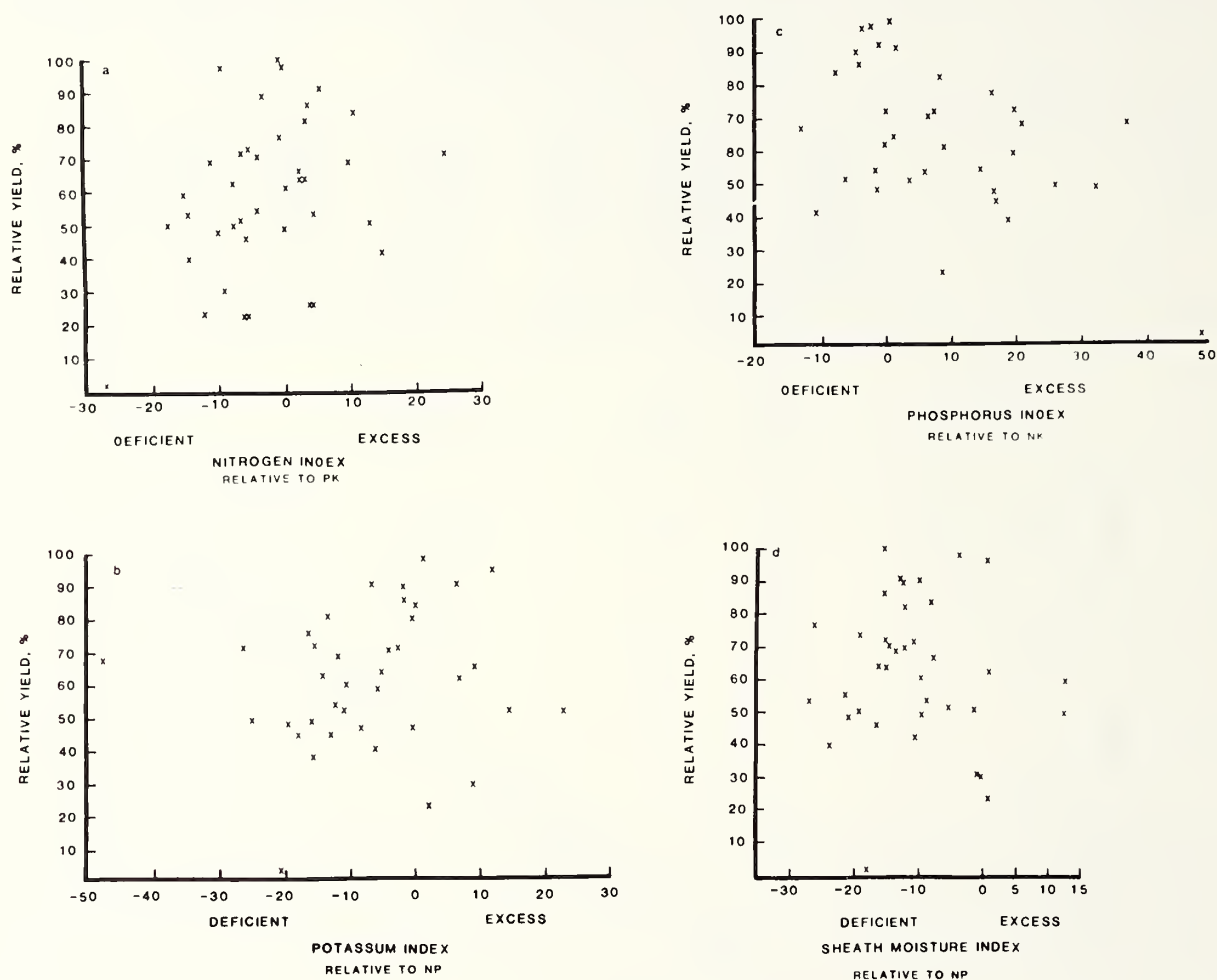


Figure 2. Relationship between relative yield (% of maximum) and N, P, K or sheath moisture indices of 3-month-old sugarcane.

Apart from the effect of moisture stress on the plant's nutrient composition, the moisture status of the plant is a critical factor affecting growth and yield. A modified DRIS approach was used to evaluate the nutrient-moisture relationship. DRIS indices based on ratios involving N, P, and sheath moisture (M) suggested that the moisture status was the factor limiting crop growth in 82% of the fields of 3-month-old cane surveyed (Table 7). Based on a normal sheath moisture level of 83%, low tissue moisture was a limiting factor in 53.6% of the surveyed fields.

Juice quality expressed as pol and purity was not significantly influenced by the concentration of N, P, K, Ca or Mg in the leaves of 6-month-old cane. Other studies (12, 15) have reported that juice quality was significantly affected by the moisture status of the plant at harvest and that excessive N availability during the

ripening period decreases juice quality. However, the low leaf N and sheath moisture levels of the 6-month-old cane suggested that N and moisture were not major factors affecting the juice quality of the surveyed cane.

Table 7. Classification of nutrient requirements by DRIS based on ratios involving N, P, K, Ca, Mg and sheath moisture (M).

Nutrient most required	Cane age (months)		
	3	4	6
	% of fields classified		
N	50	47	100
P	9	23	-
K	41	30	-
N	16	38	98
P	2	14	2
M	82	48	-
N	25	12	56
P	5	5	-
K	27	9	-
Ca	15	19	10
Mg	28	56	34

## CONCLUSIONS

Leaf N concentration of 3-month-old cane suggested that 38% of the surveyed fields needed a supplemental application of N fertilizer. Neither P nor K appeared to be serious problems. Leaf P and K concentrations were normal or higher in 89 and 92%, respectively, of the fields. The low P and K levels probably reflected low availability of N or water. Low absolute DRIS index values indicated that nutrient imbalance was a minor factor affecting cane growth.

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## GROWTH RESPONSE OF SIX SUGARCANE CULTIVARS TO THE HERBICIDES ASULAM, DALAPON AND MSMA

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### ABSTRACT

The commercial sugarcane cultivars CP 65-357, CP 70-321, CP 72-356, CP 72-370, CP 73-351, and CP 74-383, interspecific hybrids of the genus *Saccharum*, were evaluated in two Louisiana field experiments for their tolerance to foliar applications of the postemergence herbicides asulam at 3.7 and 6.7 kg/ha, dalapon at 5.0 kg/ha and MSMA at 4.5 kg/ha. Herbicides were applied in late April to new spring growth of sugarcane as would be done for control of johnsongrass, but cultivars were maintained weed-free. Cultivar response to the herbicides was determined from early-season shoot height, mature stalk production, and cane yield. Cultivars were not injured by asulam at the standard rate of 3.7 kg/ha. Asulam at 6.7 kg/ha generally caused more initial reduction in plant height and leaf chlorosis, but only CP 72-370 had reduced yield and this in only one experiment. Dalapon reduced early-season plant height for all cultivars, but its effect on number of mature stalks and cane yield at harvest varied with cultivar: CP 72-370 and CP 65-357 were tolerant; CP 73-351 and CP 74-383 had some adverse reaction in one or both experiments; and CP 70-321 and CP 72-356 had consistent reductions in both experiments. MSMA caused temporary leaf desiccation, and generally reduced the early-season growth of all cultivars, but it did not affect mature stalk production for any cultivar. CP 74-383 and CP 72-370 exhibited greater tolerance to MSMA than the other four cultivars which had significant yield reductions in one or both experiments. These herbicide tolerance characterizations for the six cultivars provide information required for the development of efficient weed-management systems in sugarcane.

### INTRODUCTION

In Louisiana, johnsongrass [*Sorghum halepense* (L.) Pers.], itchgrass [*Rottboellia cochinchinensis* (Lour. Clayton)] and a complex of other grass and broadleaved weeds in sugarcane are routinely controlled with herbicides. Johnsongrass from rhizomes and itchgrass can be particularly troublesome in the ratoon crops. Overhead applications of asulam [methyl (4-aminophenyl) sulfonyl carbamate] can be used effectively for control, usually without significant injury to sugarcane (5, 7). Although not used as extensively as asulam, dalapon (2,2-dichloropropanoic acid) can be used as an overhead treatment for control of johnsongrass, itchgrass, bermudagrass [*Cynodon dactylon* (L.) Pers.] and annual grasses (4, 5, 7). MSMA (monosodium salt of methylarsonic acid) is not currently registered for use in sugarcane in the U. S., but it effectively controls johnsongrass and itchgrass (4, 7) and is used widely for sugarcane weed control in other countries. Overhead treatments with dalapon and MSMA can injure sugarcane, but injury is minimized by applying these herbicides in early spring when temperatures are cool and sugarcane growth is slow (4, 5).

In Louisiana three or more cultivars of sugarcane are grown on individual farms to take advantage of the best qualities of each, although any one field is planted to only one cultivar. Cultivars are replaced as higher-yielding, more disease-resistant ones are developed (1). Cultivars are known to respond differentially to herbicides: CP 44-101 and CP 52-68 were more tolerant than NCo 310 and L 60-25 to dalapon (2, 8); NCo 310 was more tolerant than CP 44-101 and CP 52-68 to diuron [N'-(3,4-dichlorophenyl)-N,N-dimethylurea] (8); CP 74-383, CP 73-351, and CP 72-356 were more tolerant than CP 48-103, CP 65-357, and CP 72-370 to terbacil [5-chloro-3-(1,1-dimethylethyl)-6-methyl-2,4(1H,3H)-pyrimidinedione] (9); and CP 72-356, CP 73-351, CP 74-383, and CP 70-321 were more tolerant than CP 65-357 and CP 72-370 to hexazinone [3-cyclohexyl-6-(dimethylamino)-1-methyl-1,3,5-triazine-2,4(1H,3H)-dione] (6, 9). The degree of tolerance to certain herbicides becomes an important characteristic of the cultivar.

The purpose of this study was to characterize the response of six currently important commercial cultivars to asulam, dalapon and MSMA.

## MATERIALS AND METHODS

Field experiments were conducted in 1983 and repeated in 1986. The sugarcane used for treatments was the spring growth of cane first harvested the previous autumn (first-ratoon crop). It had been planted in plots (5.2 m x 5.5 m) about 20 months before treatment on Mhoon silt loam soil at the U. S. Sugarcane Field Laboratory's Ardoyne Farm near Houma, Louisiana. The experiments were herbicide treatment by cultivar factorials arranged in a split-plot design with four (1983) or three (1986) replications. Asulam at 3.7 or 6.7 kg/ha, dalapon at 5.0 kg/ha, MSMA at 4.5 kg/ha, and untreated control were whole plots, and commercial cultivars - CP 65-357, CP 70-321, CP 72-356, CP 72-370, CP 73-351, and CP 74-383 - were subplots arranged in randomized complete blocks. Herbicide rates are expressed as the amount of active ingredient (asulam and MSMA) or acid equivalent (dalapon) applied broadcast to a hectare of sugarcane.

Plots were maintained weed free by treating with atrazine [6-chloro-N-ethyl-N'-(1-methylethyl)-1,3,5-triazine-2,4-diamine] at 2.2 kg/ha following planting and each spring thereafter and by supplementary hand weeding as required. Experiments have shown that such atrazine treatments are not phytotoxic to sugarcane (R. W. Millhollon, unpublished data). Herbicide treatments were applied on April 26, 1983 (Exp. 1) or May 6, 1986 (Exp. 2); the cane ranged from 51 to 76 cm in overall height at the time of treatment. Commercial formulations of the sodium salt of asulam, MSMA, or the sodium salt of dalapon were applied over-the-top of sugarcane foliage in water sprays of 380 l/ha containing a 0.25% (v/v) commercial nonionic surfactant. Herbicides were applied on a 90-cm band over rows 80 cm wide so that all sugarcane leaves were wetted. The mean daily maximum and minimum temperatures for the period two weeks before to two weeks after herbicide treatment were 24.5 C and 16.0 C for Experiment 1 and 29.0 C and 18.8 C for Experiment 2. Rainfall of about 5.0 cm was recorded for each experiment within this same period but no rainfall occurred within 24 hours of treatment.

The effect of treatments on growth of cane was determined from shoot heights taken about 30 days after treatment. In Experiment 1, six randomly selected shoots per plot were measured from the ground to the top of the leaf canopy (overall height), whereas in Experiment 2, ten randomly selected shoots/plot were measured from the ground to the top visible dewlap. The number of harvestable stalks/plot (those more than about 1.2 m tall) was counted in September; the weight of cane/plot was determined in early November when the cane was cut mechanically and burned. A 15-stalk sample of the cut cane was randomly selected from each plot and crushed in a sugarcane sample mill to extract the juice; the juice was analyzed for sucrose content using standard methods (3).

The data was analyzed as a factorial experiment in a split-plot design using standard analysis of variance (ANOVA) procedures to determine significant differences ( $P = 0.05$ ) for whole plots (herbicides), sub plots (cultivars) and the interactions. When the interaction was significant, further analyses were made using single degrees of freedom to test for differences ( $P = 0.05$ ) among cultivars after subtracting the value of the control. As an example, t/ha for the CP 65-357 control - t/ha for dalapon-treated CP 65-357 was compared with t/ha for the CP 74-383 control - t/ha for dalapon-treated CP 74-383. These data are presented as "% of control" in the tables for clarity. Interactions were interpreted from the "% of control" data, which placed all cultivars on an equal basis for comparison, and from the significant differences determined for treatment means as compared to the control.

## RESULTS AND DISCUSSION

Because of variation between experiments, data for shoot height 30 days after treatment (Table 1), number of harvestable stalks produced (Table 2), and yield as weight of cane (Table 3) are presented separately for Experiments 1 and 2. Sugar content of stalks is not presented because of the lack of significant differences in the ANOVA for herbicide treatments or for interactions. Herbicide treatment by cultivar interactions were significant for stalk number and yield of cane in each experiment, but no significant interaction was found for early-season shoot height.

All cultivars showed good tolerance to asulam at 3.7 kg/ha, the standard rate, as measured by growth and yield parameters in both Experiment 1 and 2 (Tables 1, 2, and 3). The 6.7 kg/ha rate of asulam generally was more phytotoxic than the lower rate, reducing shoot height below the control as an average of all cultivars (Table 1). In addition to shoot height reduction, leaf chlorosis was also observed for all cultivars in



Experiment 2. CP 72-370 was observed to be much more chlorotic than other cultivars in Experiment 2, and this injury, while not greatly affecting stalk number (Table 2), was associated with a significant reduction in yield of cane as compared to the control (Table 3). Yields for other cultivars were not significantly different from the control.

Table 1. Shoot height of sugarcane cultivars 30 days after application as affected by foliar herbicide treatments.

Herbicide and rate	Mean shoot height by cultivar <sup>1</sup>						Mean <sup>2</sup>
	CP 65-357	CP 70-321	CP 72-356	CP 72-370	CP 73-351	CP 74-383	
(kg/ha)	-----[cm and (% of control)]-----						
	<u>Experiment 1<sup>3</sup></u>						
Asulam - 3.7	77 (93%)	71 (92%)	93 (100%)	90 (97%)	90 (102%)	88 (100%)	85ab
Asulam - 6.7	76 (93%)	69 (89%)	89 (96%)	91 (98%)	87 (99%)	87 (99%)	83 bc
Dalapon - 5.0	74 (91%)	69 (89%)	84 (91%)	89 (96%)	85 (97%)	83 (95%)	81 c
MSMA - 4.5	75 (92%)	71 (92%)	91 (99%)	90 (98%)	91 (103%)	88 (101%)	85 ab
Control	82 (100%)	77 (100%)	93 (100%)	93 (100%)	88 (100%)	88 (100%)	87 a
	<u>Experiment 2<sup>4</sup></u>						
Asulam - 3.7	30 (95%)	32 (107%)	41 (103%)	34 (99%)	37 (101%)	38 (103%)	35 a
Asulam - 6.7	26 (84%)	30 (101%)	36 (89%)	26 (76%)	33 (90%)	35 (96%)	31 b
Dalapon - 5.0	28 (92%)	28 (95%)	36 (89%)	33 (96%)	34 (92%)	34 (92%)	32 b
MSMA - 4.5	25 (81%)	28 (92%)	35 (87%)	31 (90%)	31 (85%)	33 (90%)	31 b
Control	31 (100%)	30 (100%)	40 (100%)	35 (100%)	37 (100%)	37 (100%)	35 a

<sup>1</sup> Analysis of variance for each experiment showed no significant herbicide treatment by cultivar interaction; thus, significant differences are only indicated for herbicide treatment means calculated as an average of all cultivars.

<sup>2</sup> Means followed by the same letter are not significantly different ( $P = 0.05$ ) as determined by Duncan's multiple range test.

<sup>3</sup> Height was measured from ground to top of leaf canopy.

<sup>4</sup> Height was measured from ground to uppermost dewlap.

The difference in reaction of cultivars to asulam in the two experiments show that asulam can be quite variable in causing injury to sugarcane. Extensive observations by the authors have shown that asulam is most likely to injure sugarcane in Louisiana when it is applied from the middle of May through July, a period of both relatively high temperatures and rapid sugarcane growth. In addition to the high temperature, other stresses that appear to favor injury are drought and severe weed competition. The high rate of asulam in this study was used in an attempt to induce injury so that differences in tolerance between cultivars could be detected. CP 72-370 was injured more than other cultivars by the high asulam rate, and this response agrees with observations in commercial fields.

Dalapon reduced shoot height of all cultivars and the magnitude of the reduction appeared to be similar in both Experiment 1 and 2 (Table 1). However, dalapon affected stalk production and yield of CP 73-351 more in Experiment 2 than in Experiment 1 (Tables 2 and 3). Although the "% of control" figures generally were not significantly different among cultivars for stalk production and cane yield, CP 70-321 and CP 72-356 produced fewer stalks and lower cane yield than the controls in both experiments, indicating that they were relatively sensitive to the dalapon treatment. Similar reductions were found for CP 74-383 except for cane yield in Experiment 2. Yields for CP 72-370 and CP 65-357 were not reduced following dalapon treatment.

Table 2. Mature stalk production of sugarcane cultivars as affected by foliar herbicide treatments.

Herbicide and rate	Mean no. of stalks produced at harvest by cultivar <sup>1</sup>					
	CP 65-357	CP 70-321	CP 72-356	CP 72-370	CP 73-351	CP 74-383
(kg/ha)	-----[no/ha x 10 <sup>3</sup> and (% of control)]-----					
	<u>Experiment 1</u>					
Asulam - 3.7	70 a (103%)A	72 ab (95%)A	74 ab (98%)A	76 a (96%)A	91 a (103%)A	82 a (98%)A
Asulam - 6.7	68 a (101%)A	72 ab (95%)A	73 ab (96%)A	77 a (97%)A	87 a (98%)A	83 a (98%)A
Dalapon - 5.0	66 a (97%)AB	70 b (92%)AB	70 b (93%)AB	80 a (100%)AB	91 a (103%)A	76 b (90%)B
MSMA - 4.5	66 a (97%)A	74 ab (97%)A	71 ab (94%)A	80 a (100%)A	90 a (102%)A	83 a (98%)A
Control	68 a (100%)	76 a (100%)	75 a (100%)	79 a (100%)	88 a (100%)	84 a (100%)
	<u>Experiment 2</u>					
Asulam - 3.7	77 a (104%)A	83 a (96%)A	85 ab (94%)A	82 ab (98%)A	109 a (100%)A	96 ab (104%)A
Asulam - 6.7	75 ab (102%)AB	82 a (95%)B	86 ab (94%)B	79 b (94%)B	110 a (102%)AB	100 a (109%)A
Dalapon - 5.0	69 b (93%)AB	75 b (86%)BC	81 b (89%)BC	90 a (103%)A	92 b (85%)C	82 c (89%)BC
MSMA - 4.5	71 ab (96%)AB	83 a (95%)B	87 ab (95%)B	86 a (103%)AB	103 a (95%)B	97 ab (106%)A
Control	74 ab (100%)	87 a (100%)	91 a (100%)	84 ab (100%)	108 a (100%)	92 b (100%)

<sup>1</sup> Lower case letters are for comparison of herbicide treatment means (no/ha) within a cultivar; upper case letters are for comparison of cultivars (no/ha as % of the control) within a herbicide treatment. Means followed by the same letter are not significantly different (P = 0.05) as determined by the Duncan's multiple range test for means within a cultivar or by an LSD analysis for cultivar comparisons within a herbicide treatment.

A comparison of the "% of control" data for the effect of MSMA on growth of shoots for each cultivar indicates that MSMA was generally more phytotoxic in Experiment 2 than in Experiment 1 (Table 1). The injury caused by MSMA did not greatly affect stalk production (Table 2), but did affect yield of cane for CP 65-357, CP 70-321, CP 72-356, and CP 73-351 in one experiment as shown by the comparison of actual yields with the controls (Table 3). CP 74-383 and CP 72-370 were not affected by MSMA treatment in either experiment.



Table 3. Yield of sugarcane cultivars as affected by foliar herbicide treatments.

Herbicide and rate	Mean yield of cane at harvest by cultivar <sup>1</sup>					
	CP 65-357	CP 70-321	CP 72-356	CP 72-370	CP 73-351	CP 74-383
(kg/ha)	-----[t/ha and (% of control)]-----					
<u>Experiment 1</u>						
Asulam - 3.7	76 a (101%)A	78 ab (96%)A	79 ab (97%)A	76 a (96%)A	85 a (103%)A	85 a (97%)A
Asulam - 6.7	76 a (101%)A	77 ab (95%)A	79 ab (96%)A	78 a (98%)A	80 b (97%)A	85 a (96%)A
Dalapon - 5.0	73 ab (96%)AB	75 b (92%)B	75 b (91%)B	77 a (96%)AB	83 ab (101%)A	80 b (90%)B
MSMA - 4.5	72 b (95%)B	79 ab (97%)AB	77 b (93%)B	80 a (100%)AB	85 a (103%)A	87 a (98%)AB
Control	76 a (100%)	81 a (100%)	82 a (100%)	80 a (100%)	82 ab (100%)	88 a (100%)
<u>Experiment 2</u>						
Asulam - 3.7	82 a (103%)A	83 ab (97%)A	82 ab (96%)A	76 ab (95%)A	91 a (100%)A	83 a (102%)A
Asulam - 6.7	72 b (91%)A	82 ab (96%)A	81 ab (95%)A	71 b (90%)A	89 a (98%)A	82 a (101%)A
Dalapon - 5.0	79 ab (100%)A	77 b (90%)AB	77 b (90%)AB	76 ab (96%)A	75 b (82%)B	81 a (100%)A
MSMA - 4.5	73 b (93%)AB	78 b (92%)B	78 b (91%)B	76 ab (96%)AB	78 b (86%)B	84 a (104%)A
Control	79 ab (100%)	85 a (100%)	86 a (100%)	79 a (100%)	91 a (100%)	81 a (100%)

<sup>1</sup> Lower case letters are for comparison of herbicide treatment means (t/ha) within a cultivar; upper case letters are for comparison of cultivars (t/ha as % of the control) within a herbicide treatment. Means followed by the same letter are not significantly different (P = 0.05) as determined by the Duncan's multiple range test for means within a cultivar or by an LSD analysis for cultivar comparisons within a herbicide treatment.

This study showed that dalapon and MSMA are more phytotoxic to sugarcane than the standard asulam treatment. It also showed that the cultivars in this study varied in their tolerance to asulam, dalapon and MSMA. Such knowledge is of value to sugarcane producers because the objective of an efficient herbicide weed control program is to selectively control weeds so that a sugarcane cultivar can achieve near to its maximum yield potential.

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## EFFICIENCY OF *IN VITRO* PROPAGATION OF SUGARCANE PLANTS BY DIRECT REGENERATION FROM LEAF TISSUE AND BY SHOOT-TIP CULTURE

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### ABSTRACT

The efficiency of *in vitro* propagation of sugarcane cultivars CP 65-357 and CP 70-321 by direct regeneration from leaf tissue and shoot-tip culture was studied. Plant production by direct regeneration from leaf roll sections was low (4 to 18 plants/leaf roll). In shoot-tip culture, 85 and 90% of the initial shoot-tips of CP 65-357 and CP 70-321 were advanced to the shoot-proliferation stage, respectively. The estimated production by shoot-tip culture for six transfers in the shoot-proliferation medium was over 27,500 plants for CP 65-357 and over 7,000 plants for CP 70-321. The best liquid rooting medium formulation tested for cultivar CP 65-357 contained 1/2 concentration of Murashige and Skoog salts and 60 g/l sucrose. Three regimes of daylength and temperature were compared for ability to maintain *in vitro* cultures without transfer.

### INTRODUCTION

Micropropagation of sugarcane offers the opportunity to produce large numbers of disease-free plants for commercial and research applications provided that the donor plants are disease-free (1). Two *in vitro* methods suggested for the rapid propagation of sugarcane are direct regeneration of plants from leaf tissue (3) and plant propagation from shoot-tip cultures (2). The purpose of this study was to compare the efficiency of the direct regeneration method as described (3) with a modified shoot-tip culture procedure for the rapid propagation of two leading Louisiana commercial cultivars of sugarcane. Modifications of the rooting medium of the shoot-tip culture and conditions of daylength and temperature for maintenance of *in vitro* cultures are reported.

### MATERIALS AND METHODS

Two *in vitro* methods were used to propagate plants of sugarcane cultivars CP 65-357 and CP 70-321. Initial success rate to establish *in vitro* culture, time required to produce plants capable of surviving in the field, and the propagation rate of plants produced per original culture were determined.

*In vitro* cultures were maintained at 26 C under light which consisted of indirect sunlight supplemented with fluorescent lights (Westinghouse Agro-Lite<sup>1</sup>, 20 watt, about 20 cm above the vessels). Plants were maintained in the greenhouse for two weeks to three months before transplanting to the field.

Direct regeneration - Apical portions of healthy stalks of sugarcane cultivars CP 65-357 and CP 70-321 were stripped, surface sterilized, and the immature leaf roll just above the apical meristem cut transversely into six to eight, 3 mm-thick sections. These were placed on agar medium containing Murashige and Skoog (MS) salts (6), 20 g/l sucrose, 2 mg/l kinetin, and 5 mg/l naphthaleneacetic acid (3). As shoots arose from the cut surface of the leaf roll tissue, they were separated and cultured on agar medium containing MS salts, 20 g/l sucrose, and 2 mg/l indolebutyric acid (IBA) until roots were formed (3). Plants were placed in Model 200 Todd planter flats (5.2 x 5.2 x 7.6 cm cavities) (Speedling, Inc., Sun City, FL)<sup>1</sup> filled with vermiculite and kept in the laboratory for 24-48 hours before being moved to the greenhouse.

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<sup>1</sup>Mention of a trademark or proprietary product does not constitute a guarantee or warranty of the product by the U. S. Department of Agriculture, and does not imply its approval to the exclusion of other products that may also be suitable.



Shoot-tip culture - The shoot tip (approximately 4 mm long x 4 mm in dia) was aseptically excised from the apical portion of healthy stalks by completely removing the leaf roll tissue. The shoot tip was placed in 20 ml of broth containing MS salts, 14 mg/1 of a commercial, 15-30-15, fertilizer (Miracle-Gro, Stern's Miracle-Gro Products, Inc., Port Washington, N. Y.)<sup>1</sup>, 20 g/1 sucrose, 0.1 mg/1 gibberellic acid, and 0.01 mg/1 IBA to stimulate shoot elongation (2). Shoot tips were unsupported in the Magenta GA-7 Vessels (7.6 x 7.6 x 10.2 cm) (Magenta Corporation, Chicago, IL 60641)<sup>1</sup> and were agitated on an orbital shaker at 40 revolutions per minute.

After shoot tips reached 10-20 mm in length, they were transferred to 20 ml of broth containing MS salts, 70 mg/1 of Miracle-Gro, 20 g/1 sucrose, 0.1 mg/1 kinetin, and 0.2 mg/1 benzylaminopurine for shoot proliferation (2, as amended by S. Kresovich, personal communication). At intervals of 8 to 24 days, proliferating shoots were separated into clusters with a range of 16 to 52 shoots each, and each cluster was placed in fresh shoot-proliferation medium. Multiplication was continued until the desired number of shoots was obtained. Records were kept on four clusters of two original shoot tips per transfer per cultivar.

Following shoot proliferation, clusters were placed in 20 ml of broth containing MS salts, 34 mg/1 Miracle-Gro, 20 g/1 sucrose, and 2 mg/1 IBA to induce roots (3). When roots developed, plants were separated, potted individually in planter flats filled with vermiculite, and placed in the greenhouse. The propagation rate was calculated.

Rooting medium - Four rooting media in which MS salts, sucrose, and IBA concentrations differed were compared using clusters of shoots of CP 65-357. Each cluster was placed in 20 ml of medium after recording the number, size, and appearance of the shoots. Each cluster was transferred to fresh medium after two weeks and shoot number, length, and vigor and root number and length were recorded four weeks after initiation of experiment. Each treatment was replicated three times and arranged in a completely randomized design. In a second rooting study, the best medium from the first study was compared to three other media. Each treatment was replicated ten times and arranged in a completely randomized design.

Effect of daylength and temperature on maintenance of *in vitro* cultures - Shoots of CP 65-357 and CP 70-321 in clusters of approximately 20 shoots each were added to culture vessels containing 20 ml of the shoot-proliferation medium. Twenty vessels of each cultivar were placed in separate incubators set at 1) a diurnal cycle of 8 h: 16 h, day (21 C); night (12 C); 2) 8 h: 16 h, day: night (constant 20 C); and 3) 16 h: 8 h, day: night (constant 20 C). Each set of conditions was repeated in a different incubator with new cultures of each cultivar. A subjective rating of shoot condition was made at 2, 4, 6, 8 and 16 weeks.

## RESULTS AND DISCUSSION

Plants produced by both micropropagation methods formed sufficient roots after four weeks in the rooting medium to be transferred to planter flats containing vermiculite and to be placed in the greenhouse. More than 90% of the plants survived transfer to the greenhouse and, again, to the field.

Direct regeneration - The number of plants produced by the direct regeneration method is considered very low (Table 1). Plantlets were recovered from about 25% of the leaf rolls cultured. Most of the leaf-roll sections that failed to produce plantlets deteriorated within 60 days of culture. Microbial contamination did not appear to be a factor in culture establishment. The time required to initiate plantlets directly from the leaf-roll tissue ranged from 75 to 261 days with most plantlets formed within the first 125 days.

Shoot-tip culture - Of the 13 shoot tips from CP 65-357 and 20 from CP 70-321 used to initiate shoot-tip cultures, 85 and 90% were successfully advanced to the shoot-proliferation stage, respectively. Microbial contamination caused the loss of a few cultures. Shoot proliferation of two shoot tips of each cultivar is given in Table 2. In shoot-tip culture, elongation took 21 days. Following transfer of regenerated plants to the shoot-proliferation medium, the first division of shoot clusters of CP 65-357 was made at 21 days (Table 2); while clusters of CP 70-321 shoots required a transfer to fresh proliferation medium at 21 days and the first division of clusters 20 days later (Table 2).



Table 1. Production of sugarcane plants of cultivars CP 65-357 and CP 70-321 by direct regeneration from leaf roll sections.

Plant production	CP 65-357	CP 70-321
Plant initiation <sup>1</sup>		
Time required (days)	75-261	70-108
Plants regenerated (no.)	729	82
No. of donor		
Leaf rolls	41	20
Ave. no. plants/leaf roll	18	4

<sup>1</sup> As shoots were produced, they were separated from the leaf roll tissue and transferred to rooting media; other pieces of leaf roll tissue were transferred to fresh shoot initiation media. Plant initiation: initiated plants had sufficient roots to survive transfer to greenhouse.

Table 2. Shoot-tip culture multiplication of sugarcane shoots of cultivars CP 65-357 and CP 70-321 in shoot-proliferation medium.

Shoots				
Advanced (no.)	Produced (no.)	Multiplication rate (no./shoot)	Time per transfer (days)	Total time elapsed (days)
<u>CP 65-357</u>				
2 <sup>1</sup>	178	89.0	21	---
121	635	5.2	21	42
151	541	3.6	15	57
103	268	2.6	8	65
209	387	1.9	12	77
100	349	3.5	16	93
<u>CP 70-321</u>				
2	84	42.0	41	--
74	213	2.9	15	56
93	231	2.5	24	80
91	315	3.5	13	93
118	375	3.2	21	114
63	134	2.1	12	126

<sup>1</sup> Shoot multiplication was recorded for two shoot tips of each cultivar. Four clusters of shoots per tip per cultivar were advanced in each transfer.

Once roots formed on shoot-tip clusters, individual plants could be separated. Some shoot proliferation continued in the rooting medium. Rooted plants from a cluster which could not be readily separated were planted together. After approximately two weeks growth, they could be separated and planted individually.

The plant production time and the number of plantlets produced per leaf roll by the direct regeneration procedure (Table 1) were similar to those reported by Irvine and Benda (3). Cultures of CP 70-321 were less responsive to direct regeneration than cultures of CP 65-357. The rate of multiplication of CP 65-357 in shoot-tip procedure (Table 2) was similar to that reported by Hendre et al (2) for cultivar Co 740; however, the rate was less than reported by Lee (5) for cultivar RB 735275. A lower number of plants was produced in cultures of CP 70-321 after a comparable amount of time because an additional transfer was needed before shoot proliferation was sufficient to make the first division of the shoot clusters and because the average time between transfer and division of clusters was greater. Kresovich et al (4) reported similarly that CP 70-321 was less responsive than NCo 310 to callus culture. Using the multiplication rates in Table 2, the estimated production by shoot-tip culture from a single shoot tip after six transfers in shoot-proliferation medium was approximately 27,500 plants for CP 65-357 and 7,000 plants for CP 70-321 and would take approximately four months for CP 65-357 and five months for CP 70-321 from the time shoot-tips were collected till rooted plants were placed in the greenhouse.

Shoot-tip culture offers the ability to produce a large number of plants from a single shoot tip because the shoot-proliferation stage can be repeated many times. There is the potential for abnormal plant or tissue formation after many cycles of multiplication. Although no abnormal plants were observed after six multiplication cycles in this study, Lee (5) observed a green mass at the base of formed shoots after seven cycles. In the direct regeneration method, as previously described (3) and used here, plantlets are taken directly from the leaf roll and placed in rooting medium. Further plant production requires the initiation of new leaf-tissue cultures. If large numbers of plants were desired from direct regeneration, the transfer of newly formed plantlets on the leaf roll to a shoot-proliferation medium could be attempted.

The commercial fertilizer added to shoot-proliferation medium of the shoot-tip procedure eliminated any evidence of stress on the shoots during two-week or longer transfers. Without the supplemental nutrients, at 7-10 days after transfer, leaf tips began to brown and older leaves became chlorotic; therefore, shoot clusters were transferred to fresh medium before they were ready to be subdivided. Quantity of the shoot-proliferation medium did not appear to be the limiting factor since increasing the volume of the original medium did not eliminate the need for the additional transfer (unpublished).

Rooting medium - In the first study (Table 3), increasing the sucrose content, reducing the concentration of the MS salts, and eliminating IBA resulted in the best root development. The second study demonstrated that shoots in root-inducing media containing 60 and 90 g/l sucrose produced approximately the same number of roots; however, the roots produced at the higher concentration were slightly discolored (Table 4). Indolebutyric acid at 2 mg/l reduced shoot and root vigor, while IBA at .2 mg/l appeared to have little or no effect on rooting when combined with the increased sucrose concentration (Table 4).

Formulation H (Table 4) which contained 60 g sucrose and no IBA was the best of these formulations for the micropropagation of CP 65-357, and has been used for micropropagation of CP 70-321, CP 74-383, and CP 79-318. Roots were obtained in two weeks using formulation H compared to four weeks with formulation A in the above experiments.

Effect of daylength and temperature on maintenance of *in vitro* cultures - Shoot tip elongation and initiation of proliferation took from five to eight weeks; therefore, if cultures were available at the shoot proliferation stage, considerable time would be saved. With efficient maintenance procedures, the preservation of a collection of cultivars *in vitro* would be facilitated.

Table 3. Effect of rooting-medium formulations on shoot and root development of shoot clusters of CP 65-357 (first study).

Formulation	MS <sup>1</sup> salts concentration	Sucrose (g/l)	IBA <sup>1</sup> (mg/l)	Ave. shoot no./cluster		Ave. shoot length (mm)		Shoot vigor <sup>2</sup> 4 wk	Ave. root no./cluster 4 wk	Ave. root length (mm) 4 wk
				start	4 wk	start	4 wk			
A	IX	20	2	8	49	18	43	10	17	15
B	1/2X	90	0	8	29	19	42	10	51	23
C	IX	90	2	9	16	17	16	4	20	8
D	1/2X	90	2	8	23	18	23	5	50	13

<sup>1</sup> MS = Murashige and Skoog (6); IBA = indolbutyric acid.

<sup>2</sup> Scale of 1-10, with 1 = very poor shoot condition, survival doubtful and 10 = excellent shoot vigor, no evidence of stress. All shoots initially rated 10.

Table 4. Effect of rooting-medium formulations on shoot and root development of shoot clusters of CP 75-357 3 wk after transfer to medium (second study).

Formulation	MS <sup>1</sup> salts concentration	Sucrose (g/l)	IBA <sup>1</sup> (mg/l)	Ave. shoot vigor <sup>2</sup>	Ave. shoot no./cluster	Ave. root no./cluster	Root appearance	
							Color	Vigor
E	IX	0	2.0	8	23	0	--	
F	1/2X	60	0.2	7	24	>50	white	vigorous growth
G	1/2X	60	2.0	6	18	3	brown	poor growth
H	1/2X	60	0.0	10	26	>50	white	vigorous growth
B	1/2X	90	0.0	9	23	>50	slightly brown	vigorous growth

<sup>1</sup> MS = Murashige and Skoog (6); IBA = indolbutyric acid.

<sup>2</sup> Scale of 1-10, with 1 = very poor shoot condition, survival doubtful and 10 = excellent shoot vigor, no evidence of stress. All shoots initially rated 10.

In the 8 h: 16 h, day (21 C): night (12 C) diurnal cycle, some growth and tillering continued although at a much reduced rate. Shoot counts doubled in both cultivars after eight weeks. Although cultures were extensively yellowed, all cultures remained viable after 16 weeks without transferring to fresh medium (Table 5). Most cultures would probably have survived longer. Under constant temperature of 20 C, length of the light period became important (Table 5). A longer light period was needed to maintain green shoots longer than ten days.

Shoot-tip culture offered a clear advantage as a method for large-scale propagation of sugarcane. In the subsequent propagation of three cultivars, it was determined that the use of the shoot-elongation medium was unnecessary and shoot tips could be placed directly into the shoot-proliferation medium. There also appears to be no advantage in the direct-regeneration method of propagation for freeing plants from sugarcane mosaic virus (3).



Table 5. Maintenance of clusters of CP 65-357 and CP 70-321 shoots in shoot-proliferation medium as affected by photo- and thermo-period.

Treatment				Cultivar	Condition of shoots <sup>1</sup>				
Light		Dark			2 wk	4 wk	6 wk	8 wk	16 wk
Hours	Temp (C)	Hours	Temp (C)						
8	21	16	12	CP 65-357	G	G	G	MY	EY,T
				CP 70-321	G	G	MY	MY	EY,T
12	20	12	20	CP 65-357	G	G	MY	MY,T	----
				CP 70-321	G	G	MY	MY,T	----
8	20	16	20	CP 65-357	MY	MY	MY	EY,T	----
				CP 70-321	MY	MY	EY	EY,T	

<sup>1</sup> Condition of shoots: G = green, healthy appearing shoots, no symptom of stress. MY = moderate yellowing, yellowing beginning with older leaves. EY = extensive yellowing, only youngest leaves green, obvious symptoms of stress. T = transferred and all cultures were viable.

Plants produced by both methods are currently being evaluated in the field for agronomic characters. A large number of plants produced by shoot-tip culture are currently being used in a study of sugarcane mosaic spread because they are a population of plants from a common, disease-free source and could be space planted to maintain individual stool integrity.

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## ABSTRACTS - AGRICULTURE

### EFFECTS OF BY-PRODUCT GYPSUM ON YIELD AND NUTRIENT CONTENT OF SUGAR CANE AND SOIL PROPERTIES

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An experiment was conducted to determine the effects of fluorogypsum and phosphogypsum ( $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ ) on the yield and nutrient content of sugar cane and chemical properties of the soil.

By-product gypsum was applied to a Sharkey clay soil (Vertic Haplaquept, very fine, montmorillonitic, thermic, non-acid) at rates of zero, one, two, five, and ten tons per acre of fluorogypsum and five tons per acre of phosphogypsum. Samples were taken from the Ap, AC, and C soil horizons in the plant cane and first stubble crop years.

Cane and sugar yields increased with each treatment and the ten tons per acre fluorogypsum significantly increased yield over the check plot in the plant cane. The five and ten tons per acre fluorogypsum and five tons per acre phosphogypsum significantly increased yield over the zero and one ton per acre fluorogypsum treatments in the first stubble crop year.

There were no significant differences in nutrient content of plant tissue in the plant cane year. However, S content in plant tissue with the ten tons per acre treatment was significantly higher than the zero and one tons per acre fluorogypsum in the first stubble year.

Extractable soil sulfur was significantly higher with the five and ten tons per acre fluorogypsum than with the check in both crop years. Extractable soil Ca increased significantly with the ten tons per acre fluorogypsum treatment over the other treatments. Extractable soil Mg was significantly lower the five tons per acre than the one tone per acre of fluorogypsum in the plant cane. Significant differences were obtained among treatments in some of the trace elements.

### CORRELATION OF CROP AGE WITH POPULATIONS OF SOIL INSECT PEST IN FLORIDA SUGAR CANE

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Correlation between crop age and populations of soil insect pests was measured in 18 commercial sugar cane fields in Florida. *Melanotus communis* (Gyllenhal) was the most abundant and largest wireworm species found in these fields. Wireworm populations were not significantly correlated with crop age (years) as indicated by a low correlation coefficient of -0.18. *Ligyris subtropicus* (Blatchley) was the most abundant and largest grub species found in these fields. In contrast to wireworms, grub populations were significantly correlated with crop age (years) with a correlation coefficient of +0.74. Data presented in this study indicate the importance of old sugarcane fields in harboring grub populations and these data also suggest reduced ratooning of Florida sugar cane as a possible means of grub control.

## **RATOON STUNTING DISEASE LOSSES IN FOUR COMMERCIAL SUGAR CANE CLONES IN FLORIDA**

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Yield loss due to ratoon stunting disease (RSD) of sugar cane was measured at four locations, two on sand and two on muck, in plant cane and first ratoon. At each location there were eight replications in a randomized-complete-block, split-plot design with clones as main plots and disease states (healthy or RSD infected) as sub-plots. Each sub-plot was four rows x 5.3 m surrounded by 4.6 m of clear space on four sides.

All seed cane for the trials came from a nursery at Canal Point, Florida. The nursery had been established by treating all seed cane in hot water at 51°C for two hours, then inoculating seed for half of the plots with *Clavibacter xyli* subsp. *xyli* from culture. The infection status of seedcane from plots in the increase nursery was established by examination of extracted sap for the presence or absence of *C.X.* subsp. *xyli* by light microscopy.

The variance of three parameter (sugar per tonne of cane, tonnes of cane per ha, and tonnes of sugar per ha) was analyzed for each location separately each year and for all locations and years combined. In the separate analyses, one or more clones showed a significant loss ( $P=0.5$ ) of sugar per ha due to RSD in each trial, but with little consistency with respect to clones from trial to trial. In the combined analysis, all four clones showed a significant loss in both tonnes of cane and sugar per ha, but no clone showed a significant change in sugar per tonne of cane. The percentage losses of tonnes of sugar per ha were 4.58, 4.47, 4.41, and 3.96 for CP 70-1133, CP 72-1210, CP 74-2005, and CP 65-357 respectively.

## **A PROGRESS REPORT ON HARVESTING SYSTEM PERFORMANCE AT TWO FLORIDA SUGAR MILLS**

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Field performance data were collected on hand and mechanical harvesting systems currently used by two Florida sugar mills. The study involved 46 fields of cultivar CP 72-1210, half of which were cut by hand and half by mechanical harvesters. Collected data included field conditions, harvesting losses, trash contents, and juice quality measurements for each field. The purpose of the study was to compare the field performance of the two harvesting systems and identify areas for improvement in each system. Recoverable sugar was lower with mechanical harvesting when compared to hand harvesting. Over half of the total sugar loss can be attributed to the difference in net cane between the harvesting systems. The remaining loss can be attributed to lower juice quality and undetermined or invisible losses.

## PERFORMANCE OF THE NEW SUGAR CANE VARIETY CP 79-318 IN INFIELD VARIETY TESTS

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The experimental yield data from infield variety tests of the new sugar cane variety CP 79-318, released for commercial production in 1987, are compared to the three major commercial varieties grown in Louisiana, CP 65-357, CP 70-321, and CP 74-383. This is the first opportunity to compare the yield performance of new varieties with the commercial standards when all plots are machine harvested. The preliminary results indicated that CP 79-318 compared favorably with commercial varieties in yield of sugar per hectare, tons of cane per hectare, sugar per ton, average weight per stalk and stalks per hectare. As a result of these tests, CP-318, as well as twelve varieties from this series, was introduced to the outfield tests and primary increase stations. However, only CP 79-318 was eventually released for commercial planting from this series.

## THE ROLE OF STALK DENSITY, PITH AND TUBE IN SUGAR CANE SELECTION

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A study determined the role of stalk density ( $\text{g}/\text{cm}^3$ ), pith and tube in a first line trial testing state. Eighty randomly selected sugar cane (*Saccharum* spp.) clones were replicated three times in a randomized complete-block design. Data were collected in plant cane and first ratoon crops. Variances and covariances for the traits were estimated, and broad-sense heritabilities and genetic correlations were calculated. The genetic correlations were subjected to path-coefficient analysis to determine the relative effect of stalk density and tube on stalk weight (kg), and of pith on sucrose concentration (g sucrose/kg cane).

Broad-sense heritability is the extent to which an individual's phenotype is determined by its genotype. High broad-sense heritability indicates a potential for effective selection. The broad-sense heritabilities, on a singled plot basis, for stalk density, pith and tube were  $0.028 \pm 0.005$ ,  $0.612 \pm 0.096$ , and  $0.423 \pm 0.070$ , respectively. Therefore, selection in a first line trial testing stage would be most effective for pith, tube, and stalk density, in that order.

Path-coefficient analysis was implemented to further define the genotypic correlations between trait relationships in a first ratoon crop. Stalk density and the tube were minor components of stalk weight, having direct effects of 0.170 and -0.005, respectively. The direct effect of pith on sucrose concentration was -0.005. The indirect effect of pith on sucrose concentration through its association with brix, a component of sucrose concentration, was -0.266 indicating that a negative relationship exists between pith and brix. Other results suggest that selection for clones with high brix, low pith and not tube indirectly improve stalk density.



## SOME STUDIES ON DAMAGE TO SUGARCANE BY THE SPIDER MITE *OLIGONYCHUS STICKNEYI* (McGREGOR)

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Research was conducted during 1987 and 1988 on damage by the spider mite *Oligonychus stickneyi* (McGregor) to sugarcane in Florida. Estimates of population levels of mites on a per-square-centimeter basis were made on leaves with visible dewlaps using a hand magnifier fitted with a counting grid; multiple samples on leaves were taken to obtain an average level of mites/sq cm. In commercial fields, up to 50 nymphs and/or adults/sq cm and up to 273 eggs/sq cm were observed in individual samples, but overall levels usually averaged less than three mites/sq cm. Many mites were sometimes present on lower leaves while few were on upper leaves. Observations indicated that the russetting associated with mite infestations can occur where mites feed even when only several mites are present/sq cm. Based on tests with young sugarcane plants growing in containers, russetting was more pronounced in CL 61-620 and 'CL 59-1052 when ambient temperatures were cool (e.g., average daily temperature 68°F) than when they were warmer (e.g., average daily temperature 76°F) even though mite levels were similar; almost no russetting developed under greenhouse conditions when temperatures were high (e.g., average daily temperature 95°F). In an eight-week test that began soon after shoot emergence, shoot weights indicated growth of young CL 61-620 was reduced by 5 to 9% when mite levels averaged 1.7 nymphs and adults/sq cm and a moderate amount of russetting developed. No growth reductions occurred in two other eight-week tests with young plants of this variety when mite levels averaged 0.6 to 0.7 nymphs and adults/sq cm and little or no russetting developed. In a five-week greenhouse test with CP 74-2005 beginning four weeks after emergence, mite levels averaged 2.7 nymphs and adults/sq cm but almost no russetting occurred (average daily temperature 81°F); mites reduced the growth of primary shoots in this test by 13% based on shoot weights. At average mite levels of less than 1.0/sq cm and almost no russetting, no growth reductions were detected in young CL 59-1052, CP 70-1133, or CP 72-1210 shoots in an eight-week test beginning soon after shoot emergence. No reductions in growth occurred in young CL 59-1052 shoots in two eight-week tests that began soon after shoot emergence when mite levels averaged 1.0/sq cm and light to moderate russetting occurred.

## ROLE OF VARIETIES, WEATHER CONDITIONS AND MANAGEMENT DECISIONS IN RECORD SUGAR YIELDS FOR LOUISIANA IN 1987

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Rigid selection for high sucrose content in the breeding and selection programs provided the varieties, and a combination of ideal weather conditions and management decisions provided the scenario for record sugar yields in 1987 of 110 kg/t (220 lb/t) of cane for the industry. During the period 1972 to 1987, the varieties CP 44-101, CP 48-103, CP 52-68, CP 61-37, and L 60-25 were replaced by the varieties CP 65-357, CP 70-321, CP 72-356, CP 72-370 and CP 74-384. Concurrently, sugar yields of maturity tests at the beginning of the harvest (October 1) increased from 59 kg/t (119 lb/t) of theoretical recoverable sugar per ton in 1972 to 105 kg/t (211 lb/t) in 1987. Further, end-of-harvest (December 1) sugar yields increased from 115 kg/t (230 lb/t) in 1972 to 142 kg/t (284 lb/t) in 1987. Environmental or weather conditions that undoubtedly contributed to the record yields were rainfall distribution throughout the growing season and the intensity of sunlight prior to and during the harvest. Management decisions to use the chemical ripener glyphosate and new harvesting system, i.e., 2-row harvesters and chain pliers, also contributed to these record yields by enhancing maturity and reducing the amount of trash delivered to the mill. This paper will discuss the interaction of varieties, weather conditions, and management decisions, and attempt to explain how each of these factors contributed to the record sugar yields of 1987.



## **IMPROVING SUGAR CANE VARIETIES -- WHAT ARE OUR OPTIONS?**

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Improved sugar cane varieties are products of breeding program. The Louisiana Sugar Cane Variety Development Program uses a recurrent selection breeding strategy. This strategy returns the best offspring from one generation to be used as parents for the next generation. The genetic base for this program is kept broad through cooperation with the USDA interspecific breeding program at Houma, Louisiana and the USDA breeding program at Canal Point, Florida which incorporates worldwide commercial germplasm.

Means of improving genetic advance are explored. Genetic advance (GA) or the rate of genetic improvement per year is described by the formula:  $GA = ih^2\sigma_p/y$  where  $i$  is the selection intensity,  $h^2$  is the heritability,  $\sigma_p$  is the phenotypic standard deviation and  $y$  is years per generation.

Earlier replicated testing across locations is the single best means to improve the rate of genetic advance. It simultaneously affects all elements contributing to genetic advance. Heritability is a function of genotypic, genotype by environment and error components earlier replicated testing across locations increases the accuracy of the genotype characterization. When the error and genotype by environment interaction components are decreased and the accuracy of genotypic characterization is improved, the heritability is increased. This facilitates earlier identification and return to the crossing program of superior genotypes. Earlier identification of elite parents translates into a shorter generation time and increased selection intensity.

## **INBREEDING IN THE LOUISIANA SUGAR CANE VARIETY DEVELOPMENT PROGRAM AND THE UTILITY OF INBREEDING COEFFICIENTS AND PEDIGREES IN THE VARIETY SELECTION PROCESS**

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Pedigrees were developed for sugar cane genotypes in the Louisiana variety improvement program. A SAS computer program was written to provide a pedigree and inbreeding coefficient for any Louisiana variety and ancestors of interest through the 1986 assignments. The level of inbreeding for commercial Louisiana varieties ranged from a low of 3.6 per cent for CP 70-321 to 11.1 per cent for CP 65-357. Generally, the degree of inbreeding remained low but isolated cases of up to 30 per cent were identified. Although common ancestry of a few noble canes in modern genotypes is widespread, pedigree examination made apparent the importance of new germplasm from the basic breeding program in preventing inbreeding.

Development of numerator relationship matrices using pedigrees and inbreeding coefficients is shown. Numerator relationship matrices incorporate genetic information of relatives in the selection process. The relationship matrices coupled with genetic variance-covariance matrices in mixed model analysis allows generation of best linear unbiased predictors (BLUP). These provide the most powerful value estimates of genotypes presently known.

## INFLUENCE OF PROPICONAZOLE ON EMERGENCE OF CP 74-2005

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Propiconazole (Tilt) has been demonstrated to enhance emergence of sugar cane primary shoots by controlling pineapple disease (PD) and to increase germination even in the absence of the disease. Pineapple disease, caused by the fungus *Ceratocystis paradoxa*, is an important factor in establishment of new cane stands in many areas of the world. Although it has been reported in Florida, very little is known about its distribution or importance to the Florida sugar industry. Results of a greenhouse study examining varietal susceptibility to *C. paradoxa* indicate that at least two varieties, CP 72-2086 and CP 74-2005, appear to be very susceptible. These results may help to explain the poor germination often experienced with these particular varieties in commercial production fields.

A replicated field experiment was conducted to investigate the influence of propiconazole and a growth regulator (cytogen) on emergence of the PD susceptible variety CP 74-2005. Treatments consisted of an untreated check, propiconazole applied as a five minute cold water seedpiece dip, propiconazole applied as an in-furrow spray directed at the seedpiece prior to covering, and cytogen applied as an in-furrow directed spray prior to covering. The experiment was planted on January 8 in a poorly drained organic soil to favor disease development.

Examinations of excavated seedpieces indicated PD to be the primary cause of reduced stands. Propiconazole treatments resulted in stand counts which were significantly greater than those produced by the in-furrow spray application. Cytogen did not significantly increase emergence. These results suggest that propiconazole could be used to enhance emergence of PD susceptible varieties on Florida's organic soils.

## SELECTION FOR SUGAR CANE BORER RESISTANCE IN SEEDLING PROGENIES

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Houma, Louisiana

Sugar cane clones identified as resistant to the sugar cane borer (SCB), *Diatraea saccharalis* (F.) were used to make bi-parental crosses during the 1986 crossing campaign at Canal Point, Florida. Among 11 bi-parental crosses made were intercrosses of SCB resistant 1983 CPs, SCB resistant 1983 CPs x commercial varieties, and commercial varieties x commercial varieties.

A total of 5,174 seedlings were transplanted to the field during the spring of 1987 in a 4 to 1 skip-row pattern. This pattern consisted of four rows of cane followed by one row of corn used as the inoculated host. The field and surrounding headland was then sprayed with chlorpyrifos to suppress fire ant populations. Just prior to tassling, the corn was artificially infested with approximately 10 ( $\pm 2$ ) laboratory-reared first-instar SCB by means of a hand-held inoculator. Sugar cane seedlings were selected September 25 in the plant cane crop, selecting first for SCB resistance and second for agronomic type; i.e., numbers of stalks, length and diameter of stalks, and general vigor. No attempt was made to select for brix. A total of 335 seedlings were advanced to clonal plots which will be treated similarly. Selection rate ranged from 0.9 per cent to 12.2 per cent. The cross CP 74-383 x CP 72-356 (susceptible x susceptible), included as a check, had a selection rate of 2.6 per cent.

## **ABSTRACTS - MANUFACTURING**

### **TURBIDIMETRIC EVALUATION OF NOVEL CLARIFICATION SCHEMES AND EVAPORATION**

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Ithaca, New York

S. J. Clarke  
Audubon Sugar Institute  
Louisiana Agricultural Experiment Station  
Louisiana State University Agricultural Center  
Baton Rouge, Louisiana

Turbidimetric measurements can be very informative in studies of sugar factory performance, in particular for clarifier operation and raw sugar quality. Techniques for determination of turbidity have been cumbersome, but modern instruments can greatly reduce the time and effort involved. The refractive index (and therefore the brix) of the solution has a major effect on the measured value of turbidity.

The residual turbidity of clarified juice is a useful measure of the removal of suspended material. Several novel clarification schemes involving anionic and cationic polymers and surfactants have been studied. Cationic polymers can be very effective in reducing turbidity and comparative data will be given for several chemical treatments of juice. Evaporation of juice to syrup causes formation of suspended material, e.g., the calcium salts related to scaling. Changes in turbidity through the evaporator were measured on pilot scale equipment at ASI and at three mills. These and results for other factory streams are described.

### **PARAMETERS FOR VACUUM PAN AUTOMATION**

G. L. Aleman, Retired  
Sugar Cane Growers Cooperative of Florida  
Belle Glade, Florida

The success or failure in the automatic operation of any process equipment depends mostly in the proper selection of the parameters to be monitored and/or controlled.

The purpose of this paper is to try to highlight those parameters essential in the process of massecuite boiling in vacuum pans, and to develop the necessary communication between the experienced people in the art of sugar boiling and the personnel with knowledge of the instrument equipment and resources that modern technology has made available.

### **SHORT TERM/LONG TERM COMPUTER APPLICATION FOR THE SUGAR INDUSTRY**

E. Alfonso and R. Valdes  
Okeelanta Corporation  
South Bay, Florida

As in many industries, for the past 20 years the introduction of computers has been viewed with mixed approaches. No doubt, since the wheel; it is the most revolutionary change introduced, at the fastest speed, with the widest of applications.

The use of programmable controls has been quickly accepted throughout industry worldwide. The ability to change a control scheme quickly and without component replacement is a very desirable characteristic of these



systems. With the addition of "smart" components capable of interactive control through the use of communication paths, a wider field has opened up. These pathways allow for "soft" wiring between intelligent systems which can be quickly reconfigured to allow for any change in even the most complex scheme without the need to rewire a component.

Economically this is a welcome advantage, for a technician can rapidly modify a system with a configuration terminal without ever having to make a physical change, saving on down time and labor expense. In many industries computer systems have been installed as a matter of survival, in the fastest and most developing technological explosion time in history.

#### **EVALUATIONS OF THE PERFORMANCE OF A FORCED FEED ROLLER ON THE SEVENTH MILL AT ATLANTIC SUGAR ASSOCIATION**

J. F. Alvarez, H. Cardentey, and A. Pacheco  
Atlantic Sugar Association  
Belle Glade, Florida

The performance of the Forced Feed Roller is measured against other crops in terms of imbibition and percentage of pol in bagasse. Theoretical performance is compared to actual performance. The benefits of the Forced Feed Roller are evaluated as well as the problems during the operation.

#### **COMPUTER MODEL TO ASSESS THE ECONOMIC VALUE OF A SUGAR CANE VARIETY**

S. J. Clarke and S. B. Milligan  
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Louisiana Agricultural Experiment Station  
Louisiana State University Agricultural Center  
Baton Rouge, Louisiana

A computer model was developed to estimate sugar and molasses output from a typical sugar mill for non-standard cane varieties. The program, written in the BASIC and SAS computer languages, assumes the operating conditions for a standard cane variety: a fixed mill fiber throughput, fixed evaporator load and boiling house efficiency, and values for syrup brix, molasses brix and fiber imbibition per cent. The standard cane composition may be from commercial operations or from the breeding program. The model enables comparison of varieties with different fiber, juice brix and juice purity levels in terms of sugar and molasses production per ton of cane per day. The program used in conjunction with relative harvesting, transportation and factory costs allows computation and comparison of the economic value of different varieties.

#### **CROWN WHEEL REMOVAL FROM BAGASSE ROLL**

G. Delaune, and J. Theriot  
Breux Bridge Sugar Cooperative  
Breux Bridge, Louisiana

Information is reviewed and compiled on the effects of milling without crown wheels on the bagasse rolls. Discussed are details on performance before and after removal of the crown wheels at Breux Bridge Sugar Cooperative.



## **MICROPROCESSOR CONTROL STRUCTURES FOR RAW SUGAR FACTORIES**

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Louisiana Agricultural Experiment Station  
Louisiana State University Agricultural Center  
Baton Rouge, Louisiana

The implementation of digital control in sugar factories requires an understanding of the structures and architecture available for control systems. This paper describes the available methods for control systems and shows the different areas within a factory which can be linked together to provide both process control and operational decision making. Methods of constructing a hierarchy for the control equipment is developed and different options are presented.

## **MONOCAST NYLON MILL BEARING LINERS**

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Audubon Sugar Institute  
Louisiana Agricultural Experiment Station  
Louisiana State University Agricultural Center  
Baton Rouge, Louisiana

Results and analysis of plastic inserts installed on quarterbox bearings of the bagasse roll at Breaux Bridge Sugar Cooperative. Industrial plastics are becoming more popular in areas of intensive wear, heat, or corrosion. Evaluations and assessments are based on one crop year. Further results will be accumulated during the 1988 harvest.

## **IMPROVING PERFORMANCE OF LOW-GRADE CRYSTALLIZERS**

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Audubon Sugar Institute  
Louisiana Agricultural Experiment Station  
Louisiana State University Agricultural Center  
Baton Rouge, Louisiana

M. Garcia  
St. James Sugar Cooperative  
St. James, Louisiana

Various policies of operating the low-grade crystallizers and their effects on molasses exhaustion are discussed. Comparison is made between continuous versus batch operation and three ways to reduce the massecuite viscosity, i.e. dilution with water, dilution with molasses and temperature control with no dilution, are evaluated in terms of their effects on sucrose loss. The factors limiting the flow of heavy massecuites, such as the elevation between crystallizers and the cross-sectional area of the connectors are briefly discussed.

## **CANE KNIVES CHOKE PROTECTION**

A. L. Perera  
Okeelanta Corporation  
South Bay, Florida

A description is given of a new approach for the protection of the cane knives and cane carriers against chokes due to cane overfeeding, rocks, or any large piece of metal, chain, etc. carried along with the cane. The system consists of a set of electronic speed switches that could be set at a desired speed according to the

particular conditions or preferences of each installation. A magnetic pick-up senses the signal from a small spur gear (previously attached to the free end of the cane knives shaft), and sends it to the speed switch, through a digital tachometer for a continuous readout of knife speed and an easy set up.

### **PREPARING CANE WITH AN ELECTRONIC GOVERNOR**

L. R. Zarraluqui  
Sugar Cane Growers Cooperative of Florida  
Belle Glade, Florida

A second-hand two-stage, condensing steam turbine without governor, built in 1950, was installed in the Okeelanta Sugar Factory, replacing a wrecked turbine that used to drive the first set of cane cutting knives of a 12,000 TCD tandem. Due to major differences between design and local conditions, the reapplication needed rerating the turbine through an engineering study. Also, among several options, a solid-state electronic governor was selected as a retrofit for the rerate turbine.

The governor proved to be extremely precise, and to be capable of providing unsurpassed stability to the prime move. Moreover, it happens to be remarkable reliable, too. Installation took place in the summer of 1984, during the repair season. Today, four harvests and some six million tons of cane later, there has been no downtime due to governor failure, notwithstanding the fact that the governor requires little, if any, maintenance. This paper describes the rerate, the governor and the governor characteristics.

## AMERICAN SOCIETY OF SUGAR CANE TECHNOLOGISTS EDITORIAL POLICY

### Nature of papers to be published:

Papers submitted must represent a significant technological or scientific contribution. Papers will be limited to the production and processing of sugarcane, or to subjects logically related. Authors may submit papers that represent a review, a new approach to field or factory problems, or new knowledge gained through experimentation. Papers promoting machinery or commercial products will not be acceptable.

### Frequency of publication:

The Journal will appear at least once a year. At the direction of the Joint Executive Committee, the Journal may appear more frequently. Contributed papers not presented at a meeting may be reviewed, edited, and published if the editorial criteria are met.

### Editorial Committee:

The Editorial Committee shall be composed of the managing editor, technical editor for the Agricultural Section and technical editor for the Processing Section.

The Editorial Committee shall regulate the Journal content and assure its quality. They are charged with the authority necessary to achieve these goals. The Editorial Committee shall determine broad policy. Each editor will serve for three years; he may at the Joint Executive Committee's discretion, serve beyond the expiration of his term.

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Four copies of each manuscript are submitted to the managing editor. Manuscripts received by the managing editor will be assigned a registration number determined serially by the date of receipt. The managing editor writes to the one who submitted the paper to inform the author of the receipt of the paper, the registration number which must be used in all correspondence regarding it, and the page cost of publishing.

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reviewers' statements and a copy of the technical editor's transmittal letter to the author. The reviewers' statements should not be forwarded to the author in this instance.

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## Format

Unless the nature of the manuscript prevents, it should include the following sections in the order listed: ABSTRACT, INTRODUCTION, MATERIALS and METHODS, RESULTS, DISCUSSION, CONCLUSIONS, ACKNOWLEDGMENTS, and REFERENCES. Not all the sections listed above will be included in each paper, but each section should have an appropriate heading that is centered on the page with all letters capitalized.

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Name of the author(s), institution or organization with which he is associated, and the location should follow the title of the paper.

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The abstract should be placed at the beginning of the manuscript, immediately following the author's name, organization and location.

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Number the tables consecutively and refer to them in the text as Table 1, Table 2, etc. Each table must have a heading or caption. Capitalize only the initial word and proper names in table headings. Headings and text of tables should be single spaced. Each table should be on a separate sheet.

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Drawings and photographs must be provided separately from the text of the manuscript. Type figure numbers and legends on separate pieces of paper with proper identification. Drawings and photographs should be of sufficient quality that they will reproduce legibly.

## Reference Citations

The heading for the literature cited should be REFERENCES. References should be arranged such that the literature cited will be numbered consecutively and placed in alphabetical order according to the surname of the senior author. In the text, references to literature cited can be made by number or name of author and number from list of references. (See example.) Do not use capital letters in the titles of such articles except in initial words and proper names, but capitalize words in the titles of the periodicals or books.

## Suggested Format (Examples below)

### EVALUATION OF SUGARCANE CHARACTERISTICS FOR MECHANICAL HARVESTING IN FLORIDA

J. E. Clayton and B. R. Eiland  
Agricultural Engineers, SEA, USDA, Belle Glade, Florida

J. D. Miller and P. Tai  
Research Geneticists, SEA, USDA, and Canal Point, Florida

### ABSTRACT

### INTRODUCTION

### MATERIALS AND METHODS

## RESULTS

Table 1. Varietal characteristics of nine varieties of sugarcane over three-year period at Belle Glade, Florida.

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Figure 1. Relative size of membrane pores.

## DISCUSSION

## CONCLUSIONS

## ACKNOWLEDGMENTS

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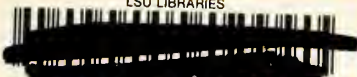








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## **PRESIDENT'S MESSAGE LOUISIANA DIVISION**

Charles Savoie, Jr.  
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Welcome to this historical event, the first joint meeting of the American Society of Sugar Cane Technologists to be held in Louisiana. As hosts of this Nineteenth Annual Joint Meeting, we of the Louisiana Division extend to you, the Florida Division membership, our membership, guests, and all other interested parties, a warm and sincere welcome. We hope you have come with large appetites to enjoy our hospitality, good food, history, and tradition of New Orleans.

The 1988 grinding season in Louisiana began with the first mill taking cane on October 3 and ended with the last mill finishing its operations on December 30. The average figures of the 20 mills reporting were: 383,912 tons of cane ground at a rate of 5,535 tons per day in just under 70 days. These figures, with an average loss time of 7.53 percent, yields about 250 tons of cane ground per hour, which is a little over an eight percent increase above the previous year. Sugar production for the 1988 crop should reach 795,000 tons, which would be the largest amount of sugar produced in a single season in the 194-year history of the Louisiana sugar industry. This would be nearly five percent more sugar than the previous industry high of 759,000 tons produced in 1963. Sugar per ton of cane for this past crop was not as good as the record yield of 225 pounds for the 1987 crop, but will be the second highest on record at about 205 pounds. Molasses processed from this crop was 41,403,000 gallons at 80° Brix, or about 5.33 gallons per ton of cane.

The total amount of cane harvested in 1988 was approximately 7,763,000 gross tons. This is almost 16.5 percent more tonnage than for the 1987 crop. Harvested acres were about 286,000, an increase of 8.7 percent over the previous year, and was the highest acreage since 1977, which had 304,000 acres. This crop produced 27.1 gross tons of sugarcane per acre, which equates to about 5,560 pounds of sugar per acre.

Some of the factors that resulted in the high sugar yields were the extended planting of higher sugar producing varieties, near ideal weather during harvest, extensive use of ripeners that increase sugar yields early in the season, and the ability of our growers to produce and harvest a higher quality sugarcane crop. This makes the second year in a row of a higher than 10 percent recovery rate per gross ton. Our previous 5-year average was 9 percent and the 25-year average was only 8.5 percent. Growers and processors should be proud of these outstanding results.

Moreover, as we do take pride in our results, we must do so with much gratitude to God for allowing us to have the factor of exceptional weather. We must also thank God for letting Tropical Storm Beryl pass us with little or no damage in early August, as well as Hurricane Florence on September 9 and 10, which passed east of the cane belt and headed north into Mississippi. Finally, on September 16, the strongest storm ever seen in the Atlantic region, Hurricane Gilbert, passed well south of us and entered into Northern Mexico.

Let us look at other factors that have given us good production the last couple of years. We have an outstanding group of research scientists and agronomists who serve our industry with knowledge and expertise. The American Sugar Cane League, the Louisiana sugar industry's representative in many matters, provides a variety of services. This organization provides extensive support and leadership in research and development, in addition to being the watchdog of legislative matters. A substantial portion, about 48 percent of the League's budget, goes toward sugarcane production and processing research. The League, in cooperation with the Louisiana State University Agricultural Center's Experiment Station and the U.S.D.A.'s Agricultural Research Service, has been most effective in its approach to the Louisiana breeding and selection program.

This program has been, and continues to be, the main research topic of the industry. Another portion of the League's budget, almost 17 percent, goes toward product promotion. The Sugar Association, Inc., with support from all segments of the industry, organized a *Sugar Promotion Program* that would alert the consuming public to the scientific facts about sugar, and to those qualities that make it the finest and safest sweetener available to man. The total current annual promotion program budget is \$4.8 million, with \$4 million allocated to advertising, and the remainder divided between public education, communication, and consumer research. In the political arena, the League has budgeted another 16 percent (which does not include its Political Action

Committee funds) to cover its legislative activities. This area will become more active with the Farm Bill coming up for renewal in 1990. The League will be helped in this area by its Washington representative, Wallace and Edwards, Inc.

The mission of the Louisiana State University Agricultural Center is to support our agricultural production and processing through the creation, development, and dissemination of new knowledge and technology. This is accomplished through the Louisiana Agricultural Experiment Station, which includes the Audubon Sugar Institute, and the Louisiana Cooperative Extension Service.

The Louisiana Farm Bureau has assisted the growers through its sugar advisory committee and, in a joint effort with the League, through a special research committee, as well as with its lobbying and funding efforts.

Through the many articles in *Sugar Y Azucar*, *The Sugar Journal*, and *The Sugar Bulletin*, a large amount of information and research has been passed on to the processors and producers. Along with these printed materials, we have the *Journal of the American Society of Sugar Cane Technologists*, which prints the technical sessions of these meetings where we have joined together to discuss and theorize our solution to our ongoing problems. The ASSCT also contributes to the future through scholarship programs to educate young men and women in the fields that will help advance our industry. Louisiana State and Nicholls State Universities, as a part of their continuing education program, offer short courses to further develop and educate our people.

Thanks are extended to our associate members and friends in those companies that provide services, products, and equipment to our industry with a sincere interest by expending their energy and ideas to help solve our problems.

What may be the most important factor in our increased production are the Louisiana sugarcane farmers themselves and the men and women who manage and operate the sugar factories. People are the ones who put the research and technology to work and take advantage of the forces of nature.

Although we now have two consecutive years of good production, thanks to God and other factors, and looking optimistically towards this year's crop, it is no time to let down our defenses or become slack in our efforts to promote our product. We still have strong opponents in Congress who want to reduce the loan rate and increase the import quotas (Bradley/Downey). Also, we must be working hard to keep the sugar section intact in the General Farm Bill. We need to help Congress understand that an unprotected domestic sugar industry could not compete with foreign subsidized industries. **There is no free trade in sugar!** An economic policy must be pursued to make sugar an efficient, progressive, and humane business. The number one goal of any sugar policy should be price stabilization.

For the United States, which is not self-sufficient in sweeteners, import quotas are very efficient, economic, and effective mechanisms. Simply put, the sugar program works. It provides domestic producers and processors an adequate return for their products; it assures the American consumer a reliable source of sugar at a stable and reasonable price; and it provides continued employment for thousands of field and factory workers, all at no cost to the federal government. Therefore, our message to Congress is "If it's not broken, don't fix it." Furthermore, for us to reach the true potential benefits of our labor, we must go beyond being good farm and mill managers. We must continue to invest, not only in research and good legislation, but also in the promotional program to better market our products. We all have a stake in this.



## **PRESIDENT'S MESSAGE FLORIDA DIVISION**

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It's a pleasure to join the Louisiana Division of the American Society of Sugar Cane Technologists at this 19th annual joint conference in New Orleans. On behalf of the Florida Division, I wish to thank you for hosting this grand event.

During the 1988-89 crop season, the Florida sugar industry experienced record yields of sugar, far surpassing anything in recorded history. A combination of good growing conditions, improved varieties, and advanced technology in our sugar mills helped us achieve a record yield of 11.32 percent industry wide.

Although Florida's 135 sugarcane growers harvested about 160,000 tons less sugarcane this year than last year's record of 13,700,000, we produced an additional 50,000 tons of raw sugar. This year, we harvested 13,585,000 tons of sugarcane producing 1,566,000 tons of sugar raw value grown on approximately 408,000 acres in the Everglades agriculture area located along the southern and eastern shores of Lake Okeechobee. This coming year's crop has good coloration and is ahead of where we were at the same time last year. We aren't seeing any evidence of the late-season freeze that caused extensive leaf damage to the young ratoon and plant cane.

Environmental issues have captured the attention of state legislators, regulatory agencies, environmental groups, and the media. Protecting and preserving Florida's environment is of utmost importance to us. In a cooperative spirit, we are developing an overall Everglades Agricultural Area (EAA) management plan to deal with wetland preservation and the downstream impacts of run-off water from sugarcane fields.

In being a leader in finding solutions to complex environmental problems, the Florida sugar industry has retained the outstanding expert in wetland ecology to address these issues. Dr. Richardson of Duke University Wetlands Center has started the first phase of a 5-year study that will contribute to a sound management plan that will mitigate undesirable downstream impacts.

In another innovative measure, Florida growers in the EAA have offered to tax themselves by forming an Environmental Protection District in order to pay for implementing environmental solutions. This district will tax only agricultural lands within the EAA and will have the ability to raise \$2-\$3 million annually. With the passing of this special district by the state legislature, followed by a referendum by landowners, we as growers will fund environmental solutions that will be of benefit to the entire South Florida region.

Turning to the federal legislative arena, trade talks will be as much of a concern as negotiations for the upcoming Farm Bill. The consensus among members of Congress is that the Farm Bill has accomplished the goals as intended; head basic farm programs in a direction that maintains strong American agriculture while, at the same time, reducing federal expenditures.

The sugar program, as part of the 1985 Omnibus Farm Bill, has worked well. It has benefited producers and consumers as well as our friendly trading partners. Even though it has worked as Congress intended, which is to provide a stable supply of sugar at a reasonable price, we continue to have opposition from large food manufacturers through the Sweetener Users Association as well as from a few vocal members of Congress and some within the administration.

For example, the soft drink industry's position is that by reducing or eliminating the sugar program, consumers will save money. Their long history of indictments and convictions for price fixing makes it clear how cynical this argument actually is. But beyond these activities, they have consistently refused to pass any cost savings on to consumers. The truth is that there is only **two cents** of sweetener in a can of soda that is selling for **sixty cents** in vending machines in Florida. The only reasons that sugar consuming corporations want to destroy the sugar program is that it means higher profits, pure and simple.

The candy industry is equally aggressive. The chocolate industry is highly concentrated with Mars and Hershey accounting for 70 percent of the market. A 1-cent cut to the farmer equals \$60 million more in profit for Mars, Inc., the maker of M&Ms; etc. According to the September 12, 1988 edition of *Fortune* magazine, the Mars family is estimated to have a total worth of \$12.5 billion; which makes them the richest family in the United States and third richest in the world behind oil tycoons, the Sultan of Brunei and King Fahad of Saudi Arabia.

We must be ever vigilant in our efforts to retain a program that allows our industry to remain competitive when faced with such stiff and powerful competition by the large industrial sugar users.

Also, the sugar program is viewed by some as a foreign trade tool rather than a farm program. In a world riddled with subsidies, we can't let the integrity of our program be forfeited for foreign policy objectives which benefit all Americans, not just sugar farmers.

Now for the good news. For the first time since the expiration of the 40-year-old Sugar Act, a presidential administration has made a positive statement in support of our sugar program. While campaigning in Twin Falls, Idaho, then Vice-President Bush said, "Under a Bush administration, the sugar program would continue even though I would try very hard to expand markets abroad by breaking down barriers to American products." He went on to say, "I know every administration gives lip service to eliminating the sugar program, but it's not going to happen unilaterally."

Furthering the administration's support, during his confirmation hearing, Secretary of Agriculture Clayton Yeutter confirmed the president's campaign pledge by supporting the sugar program. He said, "We're not going to unilaterally disarm in sugar. We absolutely cannot do so until our major trading partners are prepared to deal with the market distortions that they provide in sugar throughout the world."

Some kind of farm legislation will happen in the 101st Congress, but for how long and to what extent is uncertain. The leaders in Congress and the administration feel that the Farm Bill must be extended, but some fine tuning will occur as a result of the GATT negotiations. A united voice by the domestic sugar industry will be the key to our success in Washington and ultimately, in our home states.



# MORTALITY OF THE SUGARCANE BORER (*LEPIDOPTERA: PYRALIDAE*) SUBJECTED TO VARIOUS WATER TREATMENTS

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## ABSTRACT

Submersion of sugarcane seedpieces of cultivars CP 72-355 and CP 68-1067 in water heated to 52° C for 20 minutes, killed all sugarcane borer, *Diatraea saccharalis* (F.), larvae and pupae. The mean stalk diameters of CP 72-355 and CP 68-1067 cultivars were 24.4 mm  $\pm$  1.6 SD, and 34.6 mm  $\pm$  3.3 SD, respectively. The mean length of seed pieces used in these studies was 46 cm  $\pm$  1.3 SD. In the smaller diameter cultivar CP 72-355, it took 16 minutes for the temperature to reach 52° C inside the stalk. The highest temperature reached inside the larger diameter stalk of CP 68-1067 was 49.8° C after 20 minutes. When infested stalks were submerged in water at 25° C for 24, 48, and 72 h of submersion, survival was 90, 48 and 16%, respectively. However, it was observed that in the 72 h submersion test, only three dead larvae were found inside the stalks. Many larvae were found floating in the tank and thus had crawled out of the stalk before drowning. When larvae were placed in beakers and held underwater at 25° C for 24, 48, and 72 h, mortality was 10, 16, and 100%, respectively. Therefore, 100% mortality of sugarcane borers in sugarcane seed pieces can be achieved by submerging seed pieces in water at 52° C for 20 min or by holding them underwater at 25° C for 72 h.

## INTRODUCTION

HOT WATER treatment of sugarcane, *Saccharum* spp., has been used to control sugarcane diseases, to stimulate germination, and to destroy insect pests in seed cane for shipment. The first commercial use of heat treatment was for the control of chlorotic streak (5). Heat treatment of sugarcane seed cane has been reported to control eleven other diseases of sugarcane (1).

It has been reported that hot water treatment of sugarcane can kill the sugarcane borer, *Diatraea saccharalis* (F.) inside stalks (2). Holloway et al (3) indicated that the best treatment was to soak cane for 20 min in water heated to 50° C. He found that when infested stalks were immersed in cold water for 24 h, most sugarcane borers were killed, and all borers were dead after 72 h. After 65 h many borers were dead, but "some remained alive and reentered the stalks of cane." Ingram et al (4) reported that soaking seed cane for 72 h and 96 h in water at room temperature killed an average of 69% and 85% of the borers, respectively, and that "seed cane that had been soaked in a lake or other natural bodies of water resulted in a substantial reduction in borer infestation."

The objective of this study was to determine survival rates of sugarcane borers exposed to various water treatments.

## MATERIALS AND METHODS

Sugarcane stalks of cultivars CP 72-355 and CP 68-1067 were collected from the field, sectioned into pieces and placed into plastic tubes (62 cm long, 5 cm in diameter). These cultivars were selected because they represent the extreme in range of stalk diameter of commercial varieties grown in Florida. Stalk diameter was measured on two internodes with calipers for each seed piece from each variety. A total of 20 seed pieces from each cultivar were placed in separate plastic tubes, and each seed piece was infested with five sugarcane borer larvae (3rd or 4th instars). Sugarcane borers used in all experiments came from a laboratory colony reared on artificial media. A similar experiment was conducted with older larvae (5th instar) so that pupation would occur inside the stalk for hot water treatment evaluation. Screened caps were placed over the ends of the tubes to allow for air circulation and to confine larvae in the tubes. Tubes were kept in the laboratory at ca. 24° C for five days to allow larvae time to bore into the seed cane pieces.

Infested sugarcane pieces were removed from the tubes, placed in bundles in an open basket 47 by 36 by 44 cm and submerged in a hot water treatment tank 98 by 50 by 50 cm at  $52^{\circ} \pm 1^{\circ}$  C for 20 min. A temperature probe was inserted about 15 cm into the end of a seed piece in the center of the bundle of seed pieces and temperature readings were taken every five min. Water temperature was monitored by a second probe suspended approximately half the depth of the tank. To maintain temperature uniformity in the tank, continuous agitation was provided with a variable speed mixer. After the treatment was completed and 24 h had elapsed to allow for larval recovery, the sugarcane pieces were split with a knife, and the status (alive or dead) was determined for the first 50 larvae and the same number of pupae.

A second experiment was conducted in which the same sugarcane cultivars were each infested with 50 sugarcane borer larvae and pupae and submerged in water at room temperature (ca.  $25^{\circ} \pm 1^{\circ}$  C) for 24 h in plastic trays 46 by 38 by 13 cm. Also, a test was conducted in which sugarcane borer larvae were placed in a 400 ml beaker. The top of this beaker was covered with a screen held in place by a rubber band. By placing the 400 ml beaker in a 1,000 ml beaker and filling them both with water, larvae were completely submerged. Groups of 50 larvae were each kept submerged for 24, 48, and 72 h. Mortality was determined 24 h after removal from the tank to allow for larval recovery.

## RESULTS AND DISCUSSION

The hot water treatment of  $52^{\circ}$  C for 20 min was sufficient to kill 100% of sugarcane borer larvae and pupae on both cultivars (Table 1).

Table 1. Seed pieces of two sugarcane cultivars infested with the sugarcane borer submerged in water at different temperatures and length of exposure.

	CP 72-355		CP 68-1067	
	Alive No. (%)	Dead No. (%)	Alive No. (%)	Dead No. (%)
$52^{\circ} \pm 1^{\circ}$ C for 20 min				
Larvae	0 (0)	50 (100)	0 (0)	50 (100)
Pupae	0 (0)	50 (100)	0 (0)	50 (100)
$25^{\circ} \pm 1^{\circ}$ C for 24 h				
Larvae	38 (76)	12 (24)	45 (90)	5 (10)
Pupae	42 (84)	8 (16)	46 (92)	4 (8)

Cultivar CP 72-355 had a mean stalk diameter of  $24.4 \text{ mm} \pm 1.6 \text{ SD}$ , while CP 68-1067 had a mean of  $34.6 \text{ mm} \pm 3.3 \text{ SD}$ . The mean length of stalk pieces of both cultivars was  $46 \text{ cm} \pm 1.4 \text{ SD}$ . It took 16 min for the temperature to reach  $52^{\circ}$  C inside the stalk of cultivar CP 72-355. However, the highest temperature inside the stalk of cultivar CP 68-1067 was  $49.8^{\circ}$  C, never reaching  $52^{\circ}$  C during the 20 min exposure time. Nevertheless, these temperatures and exposures were sufficient to kill all sugarcane borers. Although there are no data on the stalk diameter of cultivars shipped from this station, the two cultivars selected for this study were considered to encompass the range in stalk diameter. Since the lethal temperature threshold of sugarcane borers is not known, the sugarcane borer might survive this hot water treatment in varieties with larger stalk diameters. However, I consider this unlikely unless a large number of stalks are treated together. In these treatments, temperature should be monitored inside stalks towards the center of the bundles.

When infested sugarcane stalks were submerged in water at 25° C for 24 h, most larvae and pupae survived. The highest larval mortality (24%) occurred on cultivar CP 72-355, while the lowest mortality (8%) was observed on pupae on the larger cultivar CP 68-1067 (Table 1). Submersion results of sugarcane borer larvae outside the stalk for 24 h were the same as when they had tunneled inside the cultivar CP 68-1067, where 10% mortality occurred (Table 2). However, about half of the larvae inside the stalk survived the 48 h exposure, and 16% survived the 72 h submersion. After 72 h, most of the larvae had left the cane pieces and were found dead floating on the water; only three dead larvae were found inside the stalks.

Table 2. Submersion of sugarcane borers larvae at 25° ± 1° C for different time periods.

Time	Larvae outside stalk (in beaker)			Larvae inside stalk <sup>1</sup>		
	Alive	Dead	Mortality (%)	Alive	Dead	Mortality %
24 h	45	5	10	45	5	10
48 h	42	8	16	24	26	52
72 h	0	50	100	8	42 <sup>2</sup>	84

<sup>1</sup> Cultivar CP 68-1067.

<sup>2</sup> 39 larvae floating on water; 3 larvae inside stalk.

A total of 76 foreign shipments comprising 1857 sugarcane clones have been shipped over the past five years (1982-1986) from the USDA Sugarcane Field Station at Canal Point, Florida. During this same period, 95 shipments were made within the United States. All sugarcane shipped from this station is heat treated in water at 52° for 45 min, and the fungicide Difolatan is added to the water at the rate of 500 ppm. The main purpose for the heat treatment has been to ensure that sugarcane shipped is disease-free, but it is equally important that they be insect-free.

The results of this study showed that hot water treatment of sugarcane seed pieces was 100% effective in killing sugarcane borers, that most sugarcane borer larvae will abandon submerged stalks at 25° C and some will survive, possibly by having access to oxygen while floating and that to obtain 100% larval mortality by soaking at 25° C, larvae must be held underwater for 72 h or longer. In addition to sugarcane borers, larvae of the sugarcane rootstalk borer weevil, *Diaprepes abbreviatus* (L.) were also killed when exposed to 52° C hot water treatment for 20 minutes (unpublished data).

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## ANALYSIS OF PERCENT BORED INTERNODE DATA COLLECTED FROM SUGARCANE BORER VARIETAL RESISTANCE EVALUATIONS

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### ABSTRACT

An improved method was selected to analyze data collected from sugarcane borer, *Diatraea saccharalis* (F.), varietal resistance evaluations. Data from outfield variety tests in 1978-81 and 1983 were reanalyzed using square-root, arcsin-square-root, and logistic transformations with analysis of variance procedures. Yearly correlations between varietal means and variances and residual plots were used as diagnostic tools to assess the adherence to the underlying assumptions behind the analysis of variance. The logistic transformation using weighted least squares was selected as the best of the methods investigated to analyze this type of information.

### INTRODUCTION

The sugarcane borer, *Diatraea saccharalis* (F.), is the key pest attacking sugarcane, a complex *Saccharum* hybrid, in Louisiana. More than 95% of the damage to this crop can be attributed to this insect (7). Varietal resistance to the sugarcane borer has been an important tool in the management of this perennial pest during the past two decades (5). In 1986, sugarcane borer resistant varieties represented 86% of the Louisiana sugarcane acreage (3). Insecticide usage and environmental contamination can be greatly reduced with the use of resistant sugarcane varieties. For example, in Louisiana during the 1973-1975 period, a highly susceptible variety, CP 61-37, received an average of 3.3 insecticide applications per season, while a resistant variety, NCo 310, averaged only 1.1 insecticide applications.

The development of new sugarcane varieties requires 14 years from the time of the initial cross until potential release as a new commercial variety (8). Beginning in the eighth year of the breeding program, new cultivars are evaluated for sugarcane borer resistance/susceptibility. From these tests, experimental cultivars will receive ratings from 0 (most resistant), to 9 (most susceptible). The primary criterion used to rate sugarcane varieties is percent bored internodes. In the eleventh year, promising varieties advance to the outfield program and are planted at various locations throughout the sugarcane growing regions of Louisiana. In these outfield tests, varieties are evaluated for various agronomic characters including sugarcane borer resistance. At the end of the season, 25-stalk samples are inspected for bored internodes and a percentage calculated for each experimental plot.

In the past, these bored internode proportions have been subjected to analysis of variance procedures either in their raw form or after one of several remedial transformations. Results of analysis of variance and mean separation performed have not always detected differences among varieties which researchers had thought to have existed (personal observation). The objective of this study was to reanalyze data collected in previous outfield studies with the anticipation of finding improved methods to efficiently rate sugarcane cultivars for sugarcane borer resistance.

The analysis of variance involves several underlying assumptions (9) including that treatment and environmental effects are additive, and experimental errors are random, independent and normally distributed about zero mean and with a common variance. Individual bored internode measurements are inherently binary, a particular internode only being able to take on values of 1 or 0, representing damage or no damage, respectively. Thus, the proportion of bored internodes in a 25-stalk sample should follow a binomial distribution, with mean  $P$  and variance  $P(1-P)/n$ , where  $n$  is the number of internodes in the sample. A problem we encounter when applying analysis of variance procedures to binomial data is that the variance is dependent on the mean and, therefore, violates the assumption of common variance. However, when the percentages range



from 20 to 80 (Figure 1), the variances are much more stable and the common variance assumption is not seriously compromised (1,6). In these outfield tests, sugarcane cultivars are grown under standard sugarcane management practices, including sugarcane borer management, making sugarcane borer resistance evaluations difficult to analyze statistically. Results often range from 1 to 35% bored internodes, a region in which the variance is not stable with respect to the varietal means. Some remedial transformations such as the square-root and arcsin-square-root have been recommended when the percentile data are outside this range (9).

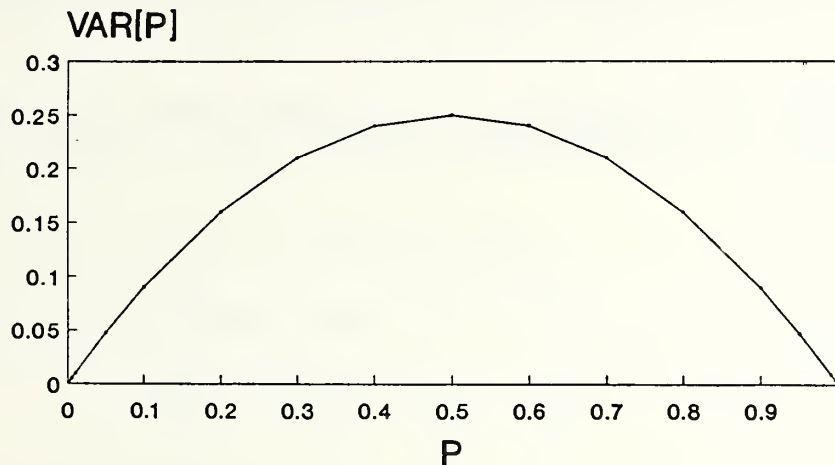


Figure 1. Relationship of the mean (P) to the variance (VAR[P]) of binomial data.

A second problem with applying analysis of variance techniques to binomial data is the assumption of normality, which is inappropriate. Additionally, the constraints placed on the response function also pose a problem. Responses from the fitted model should fall between 0 and 100% bored internodes, such that

$$0 < E(P_i) < 1$$

where  $P_i$  is the proportion of internodes bored and  $E(P_i)$  is the expected value for this proportion in the  $i$ th sample. An analysis of variance performed on proportions will not restrict the expected values between 0 and 1.

Cox (1) presents a simple method using a logistic model to satisfy the condition that the responses from the fitted model,  $P_i$ , fall between 0 and 1. If the experiment is constructed as a completely randomized design, the logistic equation is

$$E(P_i) = P_i = \exp(\mu + \tau_i) / (1 + \exp(\mu + \tau_i)),$$

where  $\mu$  is the overall mean and  $\tau_i$  a varietal effect. This equation can be linearized by the transformation

$$\pi_i = \ln(P_i / (1 - P_i)), -\infty < \pi_i < \infty,$$

where  $\pi_i$  is termed a logit, and the equation termed the logistic transformation or log-odds transformation. The linearized logistic model can now be written as

$$E(\pi_i) = \mu + \tau_i.$$

When  $P_i$  takes on values of 0 or 1 the logistic transformation is undefined, but Neter et al. (6) recommend in those instances, modification of the extreme values as

$$P_i = 1/(2n_i), \text{ when } P_i = 0,$$

$$\text{and } P_i = 1 - 1/(2n_i), \text{ when } P_i = 1,$$

where  $n_i$  are the number of internodes in the  $i$ th sample. The logistic transformation, while restricting the responses to be between 0 and 1, does not eliminate the problem of unequal variances among observations.

To address the problem of nonconstant variance, weighted least squares may be used, where the weights are equal to the inverse of the respective variances

$$w_i = 1 / \sigma_i^2$$

where  $w_i$  is the weight of the  $i$ th observation and  $\sigma_i^2$  the observation's error term variance. The weighted least squares criteria for one-way analysis of variance is

$$Q = \sum_{i=1}^n w_i (Y_i - \mu)^2$$

where  $Q$  is a weighted sums of squares and  $Y_i$  the  $i$ th observation. Minimizing  $Q$  with respect to  $\mu$  leads to

$$\mu = \frac{\sum_{i=1}^n w_i Y_i}{\sum_{i=1}^n w_i}$$

where  $\mu$  is estimated by the weighted mean of  $Y$ . When  $n_i$  is large, the variance of the logit,  $\pi_i$ , is estimated by

$$s^2(\pi_i) = 1/(n_i P_i (1-P_i))$$

such that the weights used in the weighted least squares analysis of the logits are

$$w_i = 1/s_i^2 = n_i P_i (1-P_i).$$

When the variances are known, up to a constant of proportionality, weighted least squares is optimal (4). Although, the variances must be estimated here, the weighted least squares is used to provide better estimates of the variance for making comparisons than ordinary least squares and thus should result in better analyses in the face of nonconstant variance.

## MATERIALS AND METHODS

Data collected from the 1978-81, and 1983 outfield variety evaluations were examined in this study. Each of these yearly evaluations were subdivided into plant cane (first year) and first stubble (second year) tests. Plant cane and first stubble tests were conducted at various plantations in South Louisiana. At each plantation these tests were designed as randomized complete block designs with four replicates, usually. At harvest, 25-stalk samples were randomly removed from each plot and total number of internodes and number of damaged internodes were tabulated. A proportion of damaged internodes was determined.

The raw percentiles, square-root, and arcsin-square-root transformed data were subjected to analysis of variance procedure using ordinary least squares and logistic transformed data were analyzed by weighted least squares. Residual plots generated for each year were used as diagnostics for each method. Residuals from the weighted least squares analysis of variance were weighted by the square-root of the respective weights used in the analysis of variance. Duncan's multiple range test (2) was applied as a mean separation technique. Yearly correlations between means and variances for each sugarcane variety by plantation were determined for the raw and transformed percentile data. The technique that best separated varietal means while conforming to the assumptions of the analysis of variance was selected as best.

## RESULTS

There were significant ( $P < 0.05$ ) yearly correlations between varietal means and variances for each of the five years (Table 1). These correlation coefficients were all greater than zero indicating increasing variances with increasing mean values. The arcsin-square-root transformation reduced correlations such that they were not significant at the 5% level only for the 1979 and 1981 data. The square-root transformation reduced the relationship between varietal means and variances, but did not eliminate significant correlations of 0.29 and 0.31 for 1978 and 1980, respectively. Thus, the transformations appear to reduce the problem of nonconstant variance.

Table 1. Yearly correlations between varietal means and variances among plantations without transformation and after square-root, and arcsin-square-root transformations.

Year	Without trans. <sup>1</sup>	Square-root trans.	Arcsin square-root trans.
1978	0.61 ( $<0.01$ )	0.29 ( $<0.01$ )	0.40 ( $<0.01$ )
1979	0.27 (0.01)	-0.19 (0.08)	-0.12 (0.27)
1980	0.50 ( $<0.01$ )	0.31 (0.03)	0.36 (0.01)
1981	0.47 ( $<0.01$ )	0.06 (0.54)	0.21 (0.06)
1983	0.44 ( $<0.01$ )	0.25 (0.06)	0.32 (0.02)

<sup>1</sup> Numbers in parentheses represent probabilities of obtaining greater absolute values of  $r$ .

Examination of the residual plots obtained from the ordinary least squares analysis of variance performed on the nontransformed data indicated nonconstant variance over the range of the predicted values (Figures 2-6). These residual plots displayed a characteristic "funnel" shape, i.e. the variance of the residuals showing a tendency to increase with increasing values of the predicted bored internodes. In 1979, negative values were obtained for predicted mean bored internodes for a few of the observations (Figure 3). However, with the weighted least squares analysis of variance performed on logit transformed data, the residual plots appear to be representative of residuals with constant variance across the range of the logits. The funnel-like appearance of the previous plots has been eliminated.

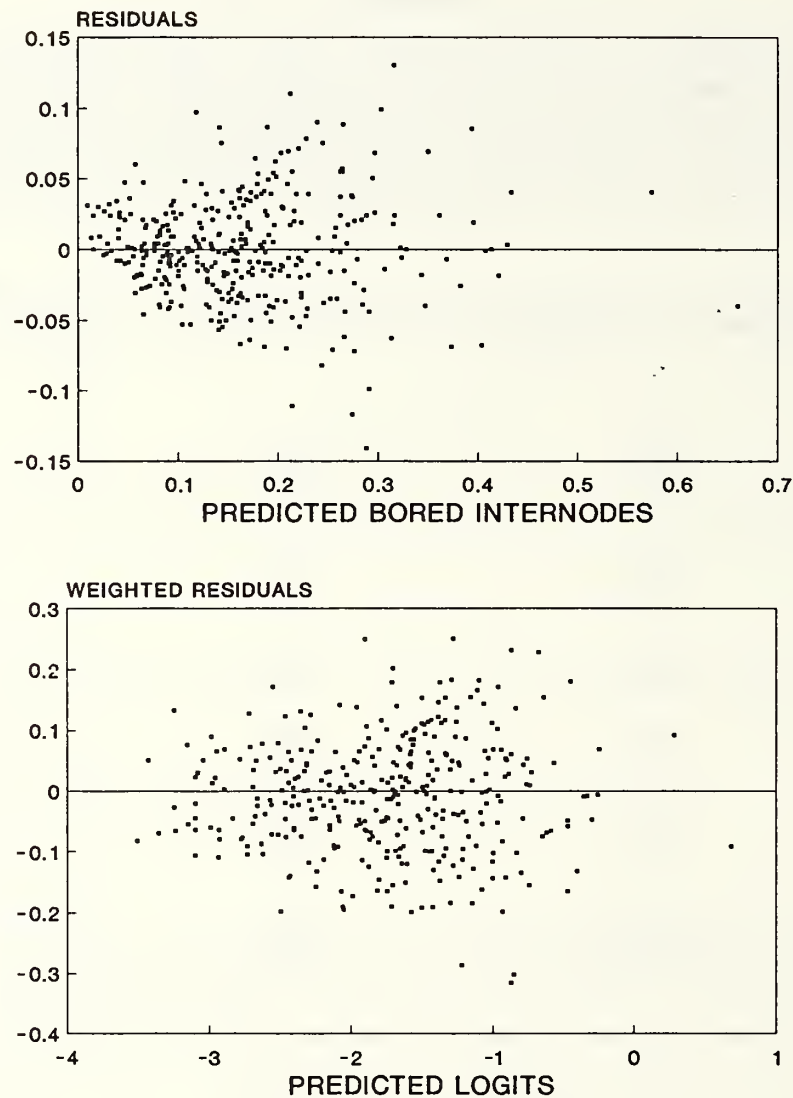


Figure 2. Relationship of predicted to residual bored internodes for raw and logit transformations using ordinary and weighted least squares, respectively, from the 1978 outfield variety tests.



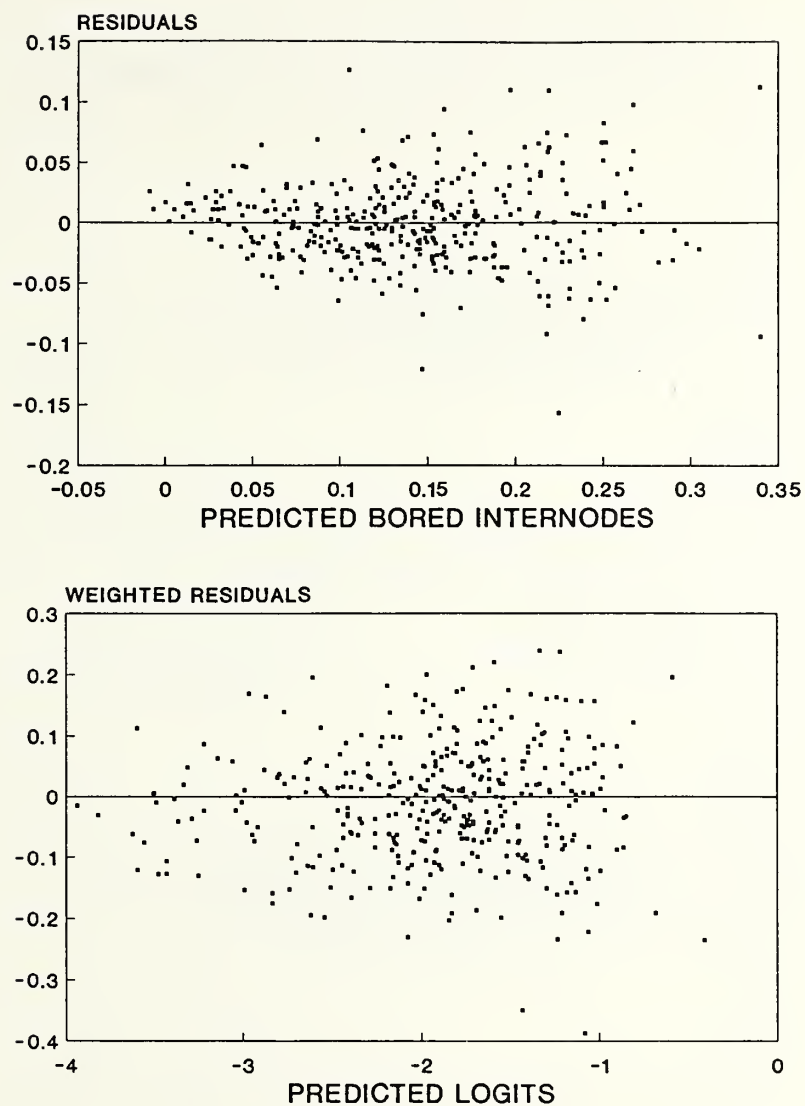


Figure 3. Relationship of predicted to residual bored internodes for raw and logit transformations using ordinary and weighted least squares, respectively, from the 1979 outfield variety tests.

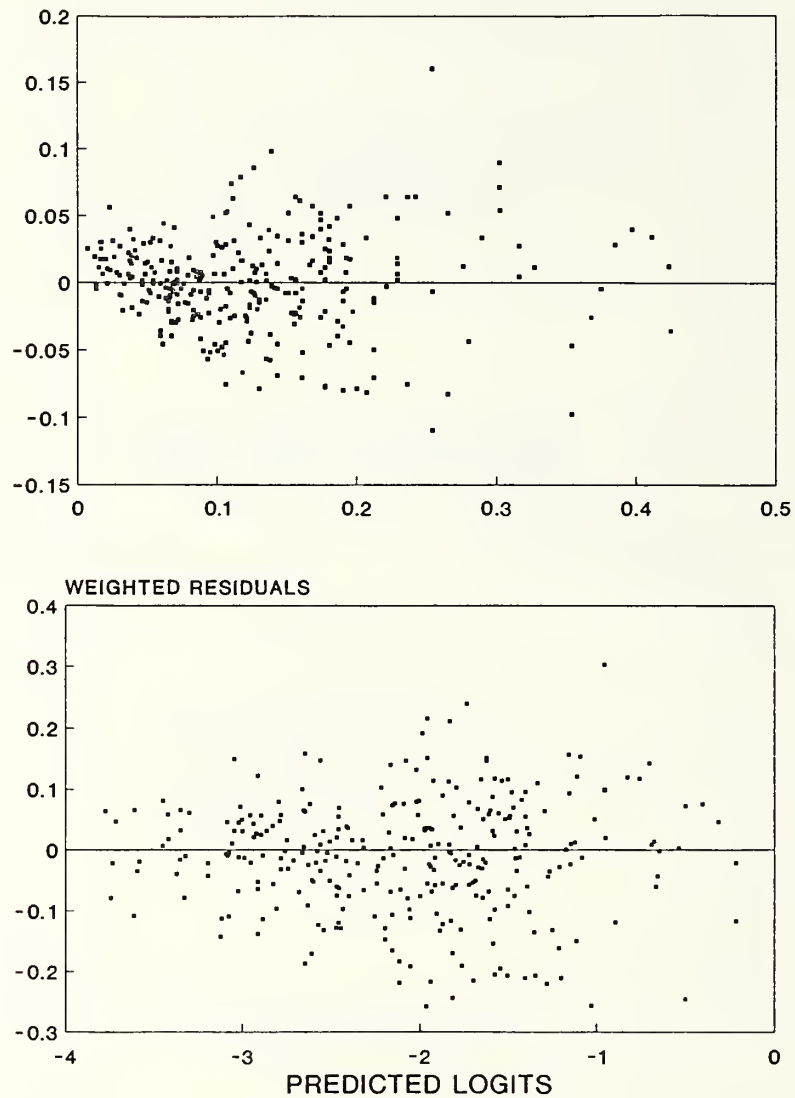


Figure 4. Relationship of predicted to residual bored internodes for raw and logit transformations using ordinary and weighted least squares, respectively, from the 1980 outfield variety tests.

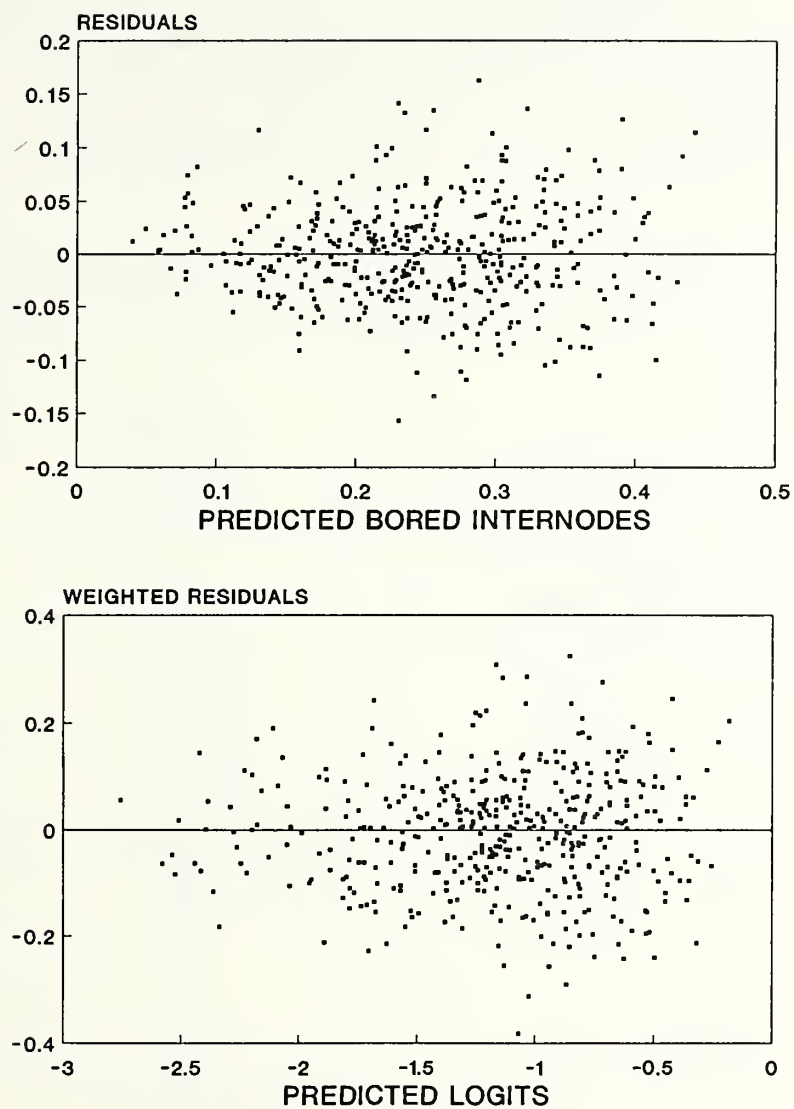


Figure 5. Relationship of predicted to residual bored internodes for raw and logit transformations using ordinary and weighted least squares, respectively, from the 1981 outfield variety tests.

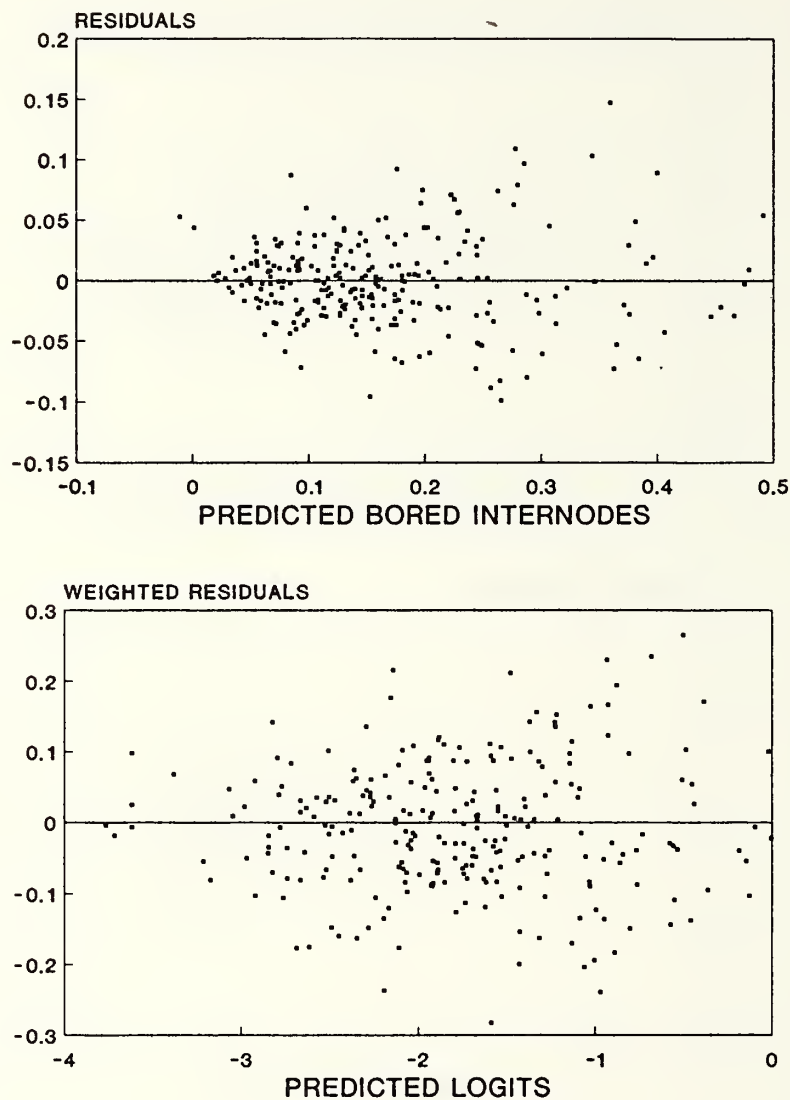


Figure 6. Relationship of predicted to residual bored internodes for raw and logit transformations using ordinary and weighted least squares, respectively, from the 1983 outfield variety tests.



Regardless of the type of transformation used, highly significant varietal effects were detected in all years for both plant cane and first stubble crops ( $F = 12.6-60.0$ ,  $df = 7, 77-12, 162$ ,  $P < 0.01$ ). Results of the Duncan's multiple range test indicated that with the weighted analysis there was greater mean separation of the logits than separation of bored internodes either in raw percentiles or after the arcsin-square-root transformation using ordinary least squares analysis of variance (Tables 2-6). The mean separations of the square-root transformed data are not included in Tables 2-6, these results were intermediate to that of the raw data and the arcsin-square-root transformation. It was noted that after transformation of the logits back to the original units of percent bored internodes, that larger differences were required to be detected as significant when percent bored internode values were large. For example, CP 73-308 and CP 67-412 have values of 15.6 and 14.1, respectively (Table 2), a nonsignificant difference of 1.5%. Whereas, CP 70-321 and CP 70-330 have values of 6.0 and 5.2, respectively, and are significantly different with a difference of only 0.8%. This is as expected since the weighted analysis permits the variance to differ with respect to the mean percent bored internodes.

Table 2. Mean sugarcane bored internodes (1978) based on ordinary least squares analysis of variance on nontransformed data and weighted least squares analysis of logistic transformed data.

Variety	<u>Plant cane</u>		
	ANOVA on % bored internodes <sup>1</sup>	ANOVA on arcsin square-root <sup>2</sup>	Weighted logistic analysis <sup>2</sup>
CP 72-355	29.7 A	29.3 A	28.9 A
CP 73-341	18.8 B	18.3 B	17.7 B
CP 73-343	17.3 BC	16.9 BC	16.4 BC
CP 73-308	16.2 BCD	15.8 BC	15.6 CD
CP 73-350	16.1 BCD	15.8 BC	15.3 CDE
CP 72-370	15.4 BCD	15.0 BCD	14.7 DEF
CP 67-412	15.3 BCD	14.6 BCD	14.1 DEF
CP 61-37	14.6 BCD	14.2 BCD	13.8 EFG
CP 72-356	14.1 BCD	13.7 BCD	13.3 FG
CP 65-357	12.8 CD	12.7 CD	12.5 G
CP 73-351	11.0 DE	10.8 D	10.5 H
CP 70-321	6.9 EF	6.3 E	6.0 I
CP 70-330	5.8 F	5.5 E	5.2 J
<u>First stubble</u>			
CP 72-355	29.3 A	28.6 A	27.8 A
CP 61-37	21.2 B	20.5 B	19.7 B
CP 67-412	18.7 C	17.9 C	17.1 C
CP 72-356	17.0 C	16.3 CD	15.5 D
CP 65-357	16.6 CD	15.2 DE	13.7 E
CP 72-370	14.3 D	13.2 E	12.1 F
CP 70-321	11.8 E	10.6 F	9.5 G
CP 70-330	9.0 F	8.4 G	7.8 H

<sup>1</sup> Means followed by the same letter in the same column are not significantly different (DMRT  $P > 0.05$ ).

<sup>2</sup> Mean values transformed back to percent bored internodes.

Table 3. Mean sugarcane bored internodes (1979) based on ordinary least squares analysis of variance on nontransformed data and weighted least squares analysis of logistic transformed data.

Variety	<u>Plant cane</u>		Weighted logistic analysis <sup>2</sup>
	ANOVA on % bored internodes <sup>1</sup>	ANOVA on arcsin square-root <sup>2</sup>	
CP 74-383	21.7 A	21.3 A	20.9 A
CP 73-343	18.8 B	18.2 AB	17.6 B
CP 23-356	18.3 BC	17.9 BC	17.4 BC
CP 73-308	18.0 BC	17.3 BCD	16.5 C
CP 65-357	16.8 BCD	15.9 BCD	14.9 D
CP 72-370	15.4 CDE	14.7 DE	14.8 D
CP 61-37	15.3 CDE	15.0 CDE	13.8 E
CP 74-322	14.7 DE	14.1 DE	13.6 E
CP 73-351	13.3 EF	12.6 E	12.6 F
CP 74-362	13.1 EF	12.9 E	11.8 G
CP 70-321	10.6 FG	9.7 F	8.9 H
CP 70-330	9.2 G	8.6 F	7.9 I
<u>First stubble</u>			
CP 72-355	20.4 A	20.0 A	19.6 A
CP 61-37	16.0 B	15.4 B	14.9 B
CP 73-343	13.2 BC	12.8 BC	12.5 C
CP 73-308	11.2 CD	10.1 CD	8.8 D
CP 65-357	10.6 CD	9.1 DE	8.1 D
CP 67-412	9.3 DE	8.7 DE	7.3 E
CP 72-370	8.4 DE	7.8 DEF	7.0 E
CP 72-356	8.3 DE	7.7 DEF	6.8 E
CP 73-351	7.9 DE	6.3 EF	4.8 F
CP 70-321	6.2 E	5.3 F	4.6 F
CP 70-330	5.6 E	5.2 F	4.3 F

<sup>1</sup> Means followed by the same letter in the same column are not significantly different (DMRT  $P > 0.05$ ).

<sup>2</sup> Mean values transformed back to percent bored internodes.

## DISCUSSION

Varietal resistance ratings to the sugarcane borer are important to sugarcane growers and consultants. These ratings can be used to better allocate their resources to monitor sugarcane borer when they stratify their sampling on sugarcane borer resistance rankings. For example, on a plantation where multiple sugarcane varieties are grown, it is useful to recognize which are the most susceptible/resistant varieties.

Neither the square-root nor the arcsin-square-root transformations eliminated the correlation between the mean and variance of this data for all years. Correlation between the mean and the variance is an indication of nonindependence, violating an assumption involved in the ordinary least squares analysis of variance. Additionally, when applying analysis of variance techniques to raw and the square-root transformed percentile data, there is the possibility of obtaining negative predicted values or predictions greater than 100%. the logistic transformation provides a method to condition the expected values such that negative predicted values can not occur and through the utilization of a weighted least squares analysis, the nonconstant variance information is incorporated into the analysis.

Table 4. Mean sugarcane bored internodes (1980) based on ordinary least squares analysis of variance on nontransformed data and weighted least squares analysis of logistic transformed data.

Variety	<u>Plant cane</u>		
	ANOVA on % bored internodes <sup>1</sup>	ANOVA on arcsin square-root <sup>2</sup>	Weighted logistic analysis <sup>2</sup>
CP 72-355	31.7 A	31.2 A	32.8 A
CP 72-356	21.7 B	21.0 B	23.1 B
CP 61-37	16.9 C	15.7 C	19.1 C
CP 74-383	16.6 C	15.8 C	18.2 C
CP 73-308	16.5 C	15.8 C	17.9 C
CP 65-357	14.1 CD	13.1 CD	15.8 D
CP 72-370	12.3 D	11.8 D	13.3 D
CP 73-351	8.5 E	8.0 E	9.6 E
CP 70-321	4.8 F	4.6 F	5.2 F
CP 70-330	4.0 F	3.8 F	4.5 G
<u>First stubble</u>			
CP 72-356	16.6 A	16.3 A	17.1 A
CP 73-308	14.7 AB	14.3 AB	15.6 B
CP 74-383	12.9 B	12.4 B	13.9 C
CP 61-37	12.2 BC	11.9 B	12.7 C
CP 72-370	9.5 C	9.0 C	10.5 D
CP 73-351	9.2 C	8.7 C	10.0 D
CP 65-357	9.1 C	8.9 C	9.7 D
CP 70-321	5.5 D	5.4 D	5.8 E
CP 70-330	3.7 D	3.6 D	3.9 F

<sup>1</sup> Means followed by the same letter in the same column are not significantly different (DMRT  $P > 0.05$ ).

<sup>2</sup> Mean values transformed back to percent bored internodes.

Table 5. Mean sugarcane bored internodes (1981) based on ordinary least squares analysis of variance on nontransformed data and weighted least squares analysis of logistic transformed data.

Variety	<u>Plant cane</u>		Weighted logistic analysis <sup>2</sup>
	ANOVA on % bored internodes <sup>1</sup>	ANOVA on arcsin square-root <sup>2</sup>	
CP 76-331	33.2 A	32.8 A	34.0 A
CP 74-383	33.3 A	33.0 A	33.8 A
CP 75-302	32.8 A	32.4 AB	33.5 A
CP 76-328	28.0 B	27.5 BC	29.1 B
CP 73-308	28.4 B	28.2 C	28.9 BC
CP 72-356	27.3 B	27.0 C	27.9 BC
CP 75-361	26.5 B	26.0 C	27.5 CD
CP 65-357	26.3 B	25.9 C	27.1 CD
CP 72-370	26.0 B	25.6 C	27.0 CD
CP 73-351	25.2 B	24.9 C	25.8 D
CP 76-301	16.8 C	16.2 D	18.0 E
CP 70-321	16.1 C	15.5 D	18.0 E
CP 70-330	13.1 C	12.7 D	13.7 F
<u>First stubble</u>			
CP 74-383	31.0 A	30.8 A	31.3 A
CP 61-37	29.4 AB	29.2 AB	29.7 B
CP 65-357	26.7 BC	26.4 BC	27.2 C
CP 72-370	25.5 CD	25.0 CD	26.4 D
CP 72-356	24.8 CD	24.4 CD	25.8 D
CP 75-002	24.5 CD	24.0 CD	25.6 D
CP 75-361	24.4 CD	24.2 CD	24.8 D
CP 73-351	22.6 D	22.2 D	23.2 E
CP 70-321	14.3 E	14.0 E	14.8 F
CP 70-330	11.3 E	10.8 F	12.1 G

<sup>1</sup> Means followed by the same letter in the same column are not significantly different (DMRT  $P > 0.05$ ).

<sup>2</sup> Mean values transformed back to percent bored internodes.

The weighted least squares analysis of variance of the logistic data, termed weighted logistic analysis, appeared to adhere to the underlying analysis of variance assumptions better than the other methods investigated and provides a linear model restricting predicted probabilities to the 0-1 interval. Post-ANOVA mean separation indicated that this type of analysis was more sensitive to smaller differences in damage among sugarcane varieties. Separations were greatest among varieties showing few bored internodes, which were not found to be significantly different using similar post-ANOVA techniques on the raw, square-root, arcsin-square-root transformed percentile data.



Table 6. Mean sugarcane bored internodes (1983) based on ordinary least squares analysis of variance on nontransformed data and weighted least squares analysis of logistic transformed data.

Variety	<u>Plant cane</u>		Weighted logistic analysis <sup>2</sup>
	ANOVA on % bored internodes <sup>1</sup>	ANOVA on arcsin square-root <sup>2</sup>	
CP 74-383	24.8 A	23.5 A	27.5 A
CP 76-331	22.9 A	22.1 A	24.7 AB
CP 72-356	21.8 A	20.9 A	23.5 B
CP 65-357	17.8 B	17.0 B	19.6 C
CP 72-370	15.3 BC	13.9 C	17.4 D
CP 78-304	14.4 C	13.2 C	16.9 D
CP 78-303	14.1 C	13.0 C	16.4 D
CP 70-321	9.9 D	9.8 D	11.9 E
CP 76-301	10.2 D	9.0 D	11.1 F
<u>First stubble</u>			
CP 74-383	22.0 A	21.0 A	24.2 A
CP 76-331	21.4 A	20.5 A	23.2 AB
CP 72-356	20.4 A	20.0 A	21.1 AB
CP 65-357	19.1 AB	18.7 AB	19.8 B
CP 72-370	16.4 B	15.6 B	18.0 C
CP 76-301	11.5 C	10.7 C	13.3 D
CP 70-321	8.9 CD	8.2 C	10.4 E
CP 70-330	6.2 D	5.7 D	7.4 F

<sup>1</sup> Means followed by the same letter in the same column are not significantly different (DMRT  $P > 0.05$ ).

<sup>2</sup> Mean values transformed back to percent bored internodes.

It is anticipated that the weighted logistic analysis may provide a reliable and efficient method to analyze these data in the future. These procedures should improve the analysis of percent bored internode data in varietal selection trials and other experimental situations.

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# **SUGARCANE YIELD REDUCTION ASSOCIATED WITH DELAYED PLANTING OF CUT SEED CANE <sup>1</sup>**

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## **ABSTRACT**

Two planting treatments of seed cane, freshly-planted and delayed-planted, were tested for effect on yield. In the plant-cane crop, the delayed-planted treatment yielded approximately 20% less cane than did the freshly-planted treatment, amounting to a loss of approximately 3,000 kg of sugar per hectare. However, no significant differences in yield were observed in the first-ratoon crop. Yield losses were attributed primarily to dehydration in delayed-planted seed cane.

## **INTRODUCTION**

In the Everglades Agricultural Area (EAA) of south Florida, sugarcane growers plant their crops during the dry season from October through December. Seed cane is cut by hand, loaded on to wagons and hand planted as whole stalks, which are then cut into pieces in the furrow. Conventional practice is to plant seed cane promptly after it is cut, ideally on the next day, but delays are common. Various investigators (1,2,3,5) have attributed adequate germination and stands to several environmental factors and production practices. Miller and Eiland (4) found that delayed covering of seed cane in the furrow retarded germination. It was suggested that sunlight (5) and desiccation were responsible. This experiment was conducted to quantify the effects of delayed planting of cut seed cane on yield.

## **METHODS AND MATERIALS**

Sugarcane cultivar CP 74-2005 was cut by hand for seed cane on February 12, 1987 to be planted in two treatments: freshly-planted and delayed-planted. The experiment was conducted on a Pahokee muck at Belle Glade, FL. The freshly-planted treatment was planted on February 13. Seed cane for the delayed-planted treatment was left on the ground as it was cut until it was planted on February 19. Double rows of whole stalks were laid into furrows and then cut into 0.5 m pieces. Paired plots of each treatment were randomized and replicated six times. Each plot contained three 60 m rows spaced 1.5 m apart. Border rows were planted around the experiment.

Plant cane was harvested on February 10, 1988 with a mechanical harvester. Weight of total cane yield was recorded for each three-row plot. The ratoon crop was hand harvested on March 14, 1989, and plot weights were obtained with a tractor-mounted boom scale. In both years ten-stalk samples were taken for milling to obtain estimates of Brix, polarity, sucrose, and purity (Table 1).

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Table 1. Mill data and estimates of yield of CP 74-2005 in plant cane and first ratoon from both planting treatments combined.

	Brix	Sucrose	Purity	kg Sugar per Mg cane
Plant cane	20.34	18.85	92.67	133
First ratoon	20.90	18.97	91.00	132

## RESULTS AND DISCUSSION

In the plant cane crop, delayed planting reduced yields in every paired-plot replicate. Cane yields were significantly ( $P = 0.05$ ) affected by delayed planting, which resulted in a 19.75% yield reduction (Table 2). This translates to an estimated average loss of over 3,000 kg of sugar per hectare. Reduced yields likely were due to exposure in the pile row for six days.

Table 2. Yield of Mg cane per hectare and estimated kg sugar per hectare for freshly and delayed planted seed cane in plant cane and ratoon crops.

Planting treatment	Plant cane		Ratoon	
	Mean plot yield (Mg of cane/ha)	Sugar yield (kg/ha)	Mean plot yield (Mg of cane/ha)	Sugar yield (kg/ha)
Fresh	114.58	15239	86.53	11509
Delayed	91.95	12229	89.26	11783
Difference	22.63	3010	n.s.	
% reduction	19.75%		n.s.	
	$t = 6.090^{**}$		$t = 0.738$ n.s.	

$^{**}t.$  = 3.169 at 10 degrees of freedom

Coleman (2) has shown that six-day storage of seed cane in a shed at 35° C and 50% relative humidity actually increased germination percent. He attributed this to inversion of sucrose, increased glucose supporting more rapid growth, and changes in auxin levels. However, in this experiment, seed cane was stored in the field where it was cut, exposing it to sunlight and drying winds. It is likely that dehydration of exposed seed cane was a major factor in reduced yield.

Sunlight may have retarded or reduced germination and subsequently reduced yield (5). The inhibitory effect of sunlight should no longer be a factor once the seed cane is planted and covered, but it was observed that emergence was delayed for longer than the six-day delay in planting. Whether there are some hormonal changes resulting from interaction of sunlight and dehydration is a topic worth investigation.

In the ratoon crop, yields of the delayed-planted plots were not significantly different from the freshly-planted plots. In fact, the delayed-planted plots had a slightly higher mean cane yield (Table 2). It is apparent that the disadvantage the delayed-planted cane suffered in the plant-cane crop was no longer a factor in the ratoon.



## CONCLUSION

Sugarcane growers in the Everglades make an effort to plant seed cane the day after it has been cut. However, given constraints such as weather, equipment, available labor, and management decisions, delayed planting is not uncommon. In quantifying the potential yield loss caused by delayed planting, this experiment suggests that planting freshly cut seed cane is worth the extra effort it may sometimes require. Prompt planting always would be warranted, especially for growers whose plant-cane crop makes up a larger portion of their total cropping cycle. Further research should be conducted on this topic in relation to different cultivars, duration of delay planting, and identification of specific factors affected, such as primary shoot numbers, tillering and general vigor.

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# **A SURVEY OF SOUTH TEXAS SUGARCANE NUTRIENT STUDIES AND CURRENT FERTILIZER RECOMMENDATIONS DERIVED FROM THIS SURVEY**

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## **ABSTRACT**

The Texas A&M Experiment Station, the USDA-ARS, Rio Farms, Inc., the Rio Grande Valley Sugar Growers, Inc. and individual growers have conducted numerous nutrient studies for sugarcane in the 16-year modern history of this South Texas crop. The publication and dissemination of results have been uneven. The essential facts derived from survey data are: 1) sugarcane in South Texas does not require potassium fertilization; 2) phosphorus fertilization is generally not required either but should be assessed and addressed by annual soil tests; 3) nitrogen (N) is the key nutrient for sustaining South Texas production; 4) applications of minor nutrient elements are not required with the exception of iron when iron deficiency chlorosis is indicated.

Fields virgin to cane require 56 kg/ha N or less in the plant year. Nitrogen fertilization in succeeding ratoons should incrementally increase as follows: first ratoon 100-157 kg/ha, second ratoon 134-190, third ratoon and thereafter 168-202. The higher rates apply to clay soils. Nitrogen should be applied in one application at planting or ratooning, but clay fields may warrant 2-3 split applications before the end of March.

## **INTRODUCTION**

In Texas, sugarcane is grown commercially in the Lower Rio Grande Valley (LRGV), an alluvial flood plain of the Rio Grande River. Soil series vary widely within short distances. River silts, clay and sandy loams, nearly pure clay and sand soils, and numerous combinations of these are represented. Nearly all are calcareous and alkaline in reaction. Sugarcane is irrigated on all these soils in this semi-arid area. With around 15,000 hectares, sugarcane is a relatively minor crop for the area with a smaller hectarage than cotton, grain sorghum, vegetables, melons, or corn, but slightly more than citrus. Cane is generally rotated with cotton, grain sorghum or corn. It is, on an average, grown for four annual harvests followed by two years of another crop, preferably cotton. The major benefit of an alternate crop is to eradicate grass weeds, which usually increase in competition over the years.

The sugar content of Texas sugarcane has been relatively low since the inception of the modern industry in 1972. The 16-year average is 8.10% yield of sugar per gross ton of cane (Table 1). Even when five freeze years averaging 6.54 are eliminated, the average for non-freeze years is only 8.81%.

Quality influencing factors such as soil salinity, high water table, irrigation water quality, insect (Mexican rice borer, sugarcane borer, white grubs, cicada grubs) damage, disease (smut, mosaic, ratoon stunting and rust), and irrigation timing come into play. Less apparent are the effects of nutrient handling, especially nitrogen (N), by growers.

In the early '70s, nutrient studies began concurrently with the re-introduction of sugarcane to South Texas. The Texas A&M Experiment Station, Weslaco, began what were to be intermittent studies. Sometimes these were conducted jointly with the USDA-ARS, Weslaco; sometimes the two entities worked independently. Rio Farms, Inc., a private research farm and also a grower, conducted tests primarily with the assistance of the USDA and the Rio Grande Valley Sugar Growers, Inc. (RGVSG). The latter is the cooperative of the 110 grower-owners and is responsible for harvesting and milling the region's cane. Individual growers occasionally installed strip or pan-sized nutrient comparisons requesting that the Co-op harvest and analyze treatments. Results of these studies were not disseminated in a form useful to growers. As a consequence, fertilizer practices have varied widely, mostly to the detriment of sugar content at harvest.

To better comprehend the interplay of soils, varieties, cane cycles, rotation cycles, nutrient application rates and timing and the resulting yield per cent cane and tons sugar per hectare, a search of published and unpublished studies and experiments was needed. From this survey, facts consistent with results could be sought and a rationale for fertilizer recommendations made.

Table 1. South Texas sugarcane sugar content by year as yield % gross cane.

Non-freeze years	Yield % cane	Freeze years	Yield % cane
		1973-74	5.80
		1974-75	7.37
1975-76	9.02		
1976-77	8.68		
1977-78	8.35 <sup>1</sup>		
		1978-79	6.32
1979-80	9.53		
1980-81	8.85 <sup>2</sup>		
1981-82	8.74		
1982-83	7.98 <sup>3</sup>		
		1983-84	5.35
		1984-85	7.87
1985-86	8.22		
1986-87	9.19		
1987-88	9.14		
1988-89	9.17		
Average	8.81		6.54
Overall Average		8.10	

<sup>1</sup> 2250 hectares of carryover cane not included.

<sup>2</sup> 932 hectares of Mexican rice borer damaged cane of this initial infestation year not included.

<sup>3</sup> Summer drought in 1982.

## METHODS

A search of published material pertinent to the Rio Grande Valley (1-32) was commenced. Bibliographical material from the first papers located lead to the discovery of others. Files of the RGVSG Agricultural Services Department were examined for relevant information. From each source located and reviewed, a one-page summary was made. This summary included the following information: 1) researchers involved; 2) where information was reported; 3) year(s) of test; 4) soil type; 5) variety(ies) in test; 6) treatments/results; and 7) conclusions.

## RESULTS AND DISCUSSION

Twenty-eight one-page summaries were compiled. Some encompassed 2-5 years testing on the same cane in succeeding ratoons. A wide range of factors was represented in the testing (Table 2). Tissue analyses

were often conducted in conjunction with the testing. As a result sheath moisture, N, P<sub>2</sub>O<sub>5</sub>, K<sub>2</sub>O, Ca and minor elements were monitored for both critical levels and Diagnostic and Recommendation Integrated System (DRIS) ratios. In addition there were two seasons during which extensive season-long surveys (17, 22) were conducted. Fields were monitored through crop logging. Again considerable data were accumulated for critical level comparisons and DRIS.

Table 2. Summation of South Texas nutrient test factors 1972-1988.

Individual crop cycle years represented:	41	
Varieties and no. of times entered in tests:		
CP 44-101	1	
CP 52-68	5	
CP 61-37	3	
CP 65-357	5	
CP 70-321	8	
CP 70-324	1	
CP 71-1038	2	
L 62-96	4	
NCo-310	12	
Nitrogen - rates and number of tests for each:		
<u>kg/ha</u>	<u>(lbs./ac.)</u>	<u>No. of tests</u>
0	(0)	30
56	(50)	13
67	(60)	1
84	(75)	2
90	(80)	3
112	(100)	17
134	(120)	8
168	(150)	13
179	(160)	2
202	(180)	2
224	(200)	14
269	(240)	2
280	(250)	1
336	(300)	2
358	(320)	2
Other nutrients and no. of tests:		
calcium		4
copper		3
iron		6
magnesium		2
manganese		3
phosphorus		11
potassium		8
sulfur		3
zinc		4
Soil types and no. of test sites on each:		
fine sandy loam		8
sandy clay loam		3
silty clay loam		5
clay loam		11
clay		3



In seven plant-cane tests, (3, 12, 14, 15, 20, 26, 27) unfertilized cane averaged 99.9 tonnes cane/ha while the highest yielding fertilized treatment (regardless of rate) in the same tests averaged 111.7. Unfertilized cane therefore produced 89.4% what fertilized cane did. The implication is that plant cane in the LRGV may require the addition of little or no N fertilizer in soils virgin to previous sugarcane production. Even in fields which has a prior history of cane, but were planted later to other crops for one or two years, there are indications that the alternate crop fertilization coupled with mineralizable N goes a long way to restoring a N reserve. Thomas (20) reported that very low yield responses could be expected from N fertilization when soil nitrate in the top 30 cm exceeded 7 ppm or 31 kg/ha. Wiedenfeld (30) confirmed this.

When tonnage yield comparisons were compiled for zero N treatments in ratoon tests (Table 3), these data indicated that it is not until the third cropping that residual N is brought into equilibrium with crop demands. Under the particular conditions of these tests, irrigation (or more precisely total water including precipitation) accounted for 66-71% of the crops' tonnages. In short, water had nearly two times the effect on tonnage that N fertilizer did.

Table 3. Ratio of tonnes cane/hectare of zero treatments to highest THC of any nitrogen fertilized treatment.

Cycle	No. of tests	$\frac{\text{THC of 0 kg N treatment}}{\text{Highest THC of any N treatment}}$	As a %
1 RT	7	$\frac{93.1}{111.6}$	83.4
2 RT	13	$\frac{79.7}{111.0}$	71.8
3 RT	11	$\frac{65.8}{99.8}$	66.0
4 RT	8	$\frac{66.1}{98.9}$	66.8
5 RT	1	$\frac{60.6}{96.1}$	63.1
Weighted Average	40	$\frac{75.0}{105.2}$	71.3

Other points made clear by the literature review were:

1. Nitrogen without adequate water is a wasted effort.
2. Split applications are not superior to a single dose except in clay soils where N could leach below the rooting zone.
3. Stalk populations depend largely on the total amount of N rather than the timing of application. Early applications favor primary and secondary stalk growth and late applications favor tertiary stalk growth.
4. Late applications of N have a deleterious effect on ripening in that cane remains green with a higher moisture content and takes up more minerals such as potassium and chloride whose higher concentrations are correlated with lower sucrose content.
5. Misuse of N has negative implications on yield % cane regardless of soil type.

6. Cane can utilize N regardless of the form in which it is initially applied.
7. Ratoon crops are more efficient users of N fertilizer than plant crops.
8. Cane needs about 1 kg N for every tonne expected (other factors not being limiting). Because N fertilization is only about 65% efficient under Valley conditions, 1.5 kg must be applied, e.g. a 100 tonne field would need 150 kg.

In the eight phosphate tests (15, 17, 26) there were no clearcut responses to phosphorus. It appears that in the early years of a cane cycle there is sufficient available phosphorus so that this element is not limiting. If a field is kept continually in cane for over three years, there exists the possibility that cane, which is a heavy feeder of phosphorus, will begin to exhaust this nutrient faster than it becomes available. Soil sampling and analyses are then needed to provide a guideline for phosphorus requirements.

Exchangeable potassium runs high in the LRGV. In the four major potassium trials (13, 21, 26, 28), no positive response was obtained. Excessive potassium levels, especially when coupled with chloride ions, may even depress sugar recovery (27). Potassium levels will fluctuate according to relationships with nitrogen and moisture status. Potassium correlations with these relationships are positive.

Magnesium applications in four tests (13) gave no response. Valley levels are at or above critical levels required for cane.

Sulphur, also applied in four tests (15) gave no response. As a nutrient, its levels in Valley soils and water are more than adequate.

Numerous tissue analyses (17, 18, 21) have shown that calcium, manganese, copper and zinc are above critical levels for Valley cane.

Iron deficiency chlorosis (24) is a problem common to Valley soils and especially to shallow rooted varieties grown in areas of high calcium carbonate cut during the soil leveling process. Ferrous sulfate (copperas) at 7-9 kg/ha in a directed spray solution works as well as more expensive chelates and complexes. Soil applied iron does not work.

Based on the foregoing information, current recommendations for LRGV sugarcane are:

Plant fields (never in cane before): No more than 56 kg N/ha and 112 kg P<sub>2</sub>O<sub>5</sub>/ha optional if a soil test indicates less than 90 kg/ha are available.

Plant fields (in cane no more than two years prior to planting or which have been deeply cut in land-leveling operations): No more than 90 kg N and P<sub>2</sub>O<sub>5</sub> optional as above.

First ratoon fields: 100-157 kg N, the higher amount based on appearance, tonnage and sugar content results from the first harvest.

Second ratoon fields: 134-190 kg N, the higher amount based on appearance and results from the first ratoon harvest.

Third ratoon fields and thereafter: 168 kg N except heavy clay soils where up to 202 kg N may be applied in up to three applications prior to the end of April. River silts and sandy loams do not require split applications since cane grown in them has a more extensive root system and may follow any leachable nitrogen to a greater depth. P<sub>2</sub>O<sub>5</sub> should be applied to bring available soil levels up to 112 kg.

Upon soil analyses, generally all nitrogen should be applied in one application at planting or ratooning. Exceptions may be: plant fields where 28 kg are applied with the seed as a starter and another 28 kg in March. Ratoon fields harvested before November 30 may also warrant one quarter of the fertilizer at ratooning and the remaining three quarters before the end of March.

The recommendations have been sent to growers. As a re-enforcement, during the harvest season, bi-weekly grower meetings are held during which the quality of cane harvested the previous two weeks is reviewed with the growers who have had fields harvested.

## CONCLUSIONS

Considerable evidence from nutrient research trials in the LRGV existed from which to confidently derive fertilizer recommendations. A compilation and summation of data contributed the following salient points:

1. Available potassium levels of LRGV soils suffice for sugarcane nutrition, but adequate nitrogen and moisture is needed for sufficient uptake.
2. Available phosphorus runs high in Valley soils, but its removal under cane croppings requires annual monitoring to keep levels in the neighborhood of 112 kg/ha.
3. With the exception of iron, minor elements are not known to be limiting in the LRGV.
4. Nitrogen is the primary nutrient to be managed in Valley sugarcane production. Modest levels ( $< 50$  kg/ha) should be applied in plant fields with rates gradually rising from 100-157 1st ratoon, 134-190 2nd ratoon to 168-202 kg/ha in the 3rd ratoon and thereafter as residual, mineralizable and applied N come into equilibrium. Cane grown on heavier clay soils where rooting is shallow may receive N rates at the higher end of the range, but caution is in order for cane grown on soils providing deep rooting.

## ACKNOWLEDGEMENTS

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## MOVEMENT OF PHOSPHORUS AND POTASSIUM FROM FERTILIZER APPLIED IN BANDS TO AN EVERGLADES HISTOSOL

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### ABSTRACT

Mobility of phosphorus and potassium from fertilizer applied in bands to sugarcane grown on a Pahokee muck soil was studied during the 1985-86 growing season. Three rates of phosphorus and potassium were applied in the bottom of the furrow prior to planting and horizontal and vertical movement were evaluated by incremental sampling of the soil profile following harvest. The highest soil phosphorus and potassium values were obtained for samples which contained the soil surrounding the original point of fertilizer placement. Soil samples taken at harvest from the area below the fertilizer band were found to have more available phosphorus and potassium than corresponding samples taken either 38 or 76 cm from the row. No lateral movement of nutrients was indicated by the data. Sodium concentration and soil pH values were found to increase proportionally to sampling depth.

### INTRODUCTION

The movement of phosphate and potassium ions through Everglades Histosols has been studied for reasons ranging from improving fertilizer efficiency to the utilization of muck soils for municipal sewage disposal. Terry and Tate (8), using intact cores of Pahokee muck soil, found that in excess of 95% of the orthophosphate content was removed from added sewage effluent as it moved down the columns. Baligar *et al.* (1) reported that the ratio of exchangeable K to soil solution K was greater for organic soils which had a long history of cultivation than for virgin soils from the same area. They postulated that there were changes in binding sites associated with subsidence which could reduce potassium losses caused by leaching. The effects of rainfall and fallow flooding on the mobility of fertilizer applied to the surface of a Pahokee muck soil was studied by Lucas (6). He showed that phosphorus mobility was dependent on the pH as well as the tillage history of the soil. For a soil with pH of 5.9, phosphorus was found to move less than 15 cm from the point of placement during a seven month period with 122 cm of rainfall. Potassium mobility was only slightly greater under similar conditions. Fallow flooding of a nearby soil with a pH of 7.1 was shown to cause greater downward potassium movement through the soil but had a very limited effect on phosphorus mobility.

Banding of fertilizers containing phosphorus and potassium has been a common practice among many commercial sugarcane growers in the Everglades Agricultural Area for a number of years. It has been assumed that a portion of the fertilizer may remain in the vicinity of the original band for at least one year following application (3). However, the actual degree of mobility and the amount of residual fertilizer available to the ratoon crop has not been investigated. This study was initiated to determine the extent of horizontal as well as vertical movement of phosphorus and potassium from a fertilizer band placed beneath the sugarcane seed piece.

### MATERIALS AND METHODS

The experiment was performed in a commercial sugarcane field which was located approximately three miles south of the Everglades Research and Education Center (EREC) near Belle Glade, FL. The soil type is classified as a Pahokee muck (euic, hyperthermic Lithic Medisaprist) and had been in sugarcane production for over 20 years. Three unreplicated plots representing three rates of phosphorus and potassium fertilization along with an unfertilized control plot were used to investigate the mobility of the two nutrients over the course of one year. The individual plots were 6 m in width by 10 m in length. The distance between rows was 1.52 m and all soil sampling was performed on or between the two internal rows of each plot. The trial location was prepared for planting on 11 January, 1985 using a standard three-row furrow plow. Fertilizer treatments were applied as uniformly as possible by hand on 15 January, 1985 to form a 5-8 cm wide band at the bottom of the

planting furrow. Fertilizer rates and sources are given in Table 1. The "medium" rates of P and K fertilization are approximately equal to EREC recommendations for plant cane based on pre-trial soil test results for the study area (4).

Table 1. Fertilizer treatments for sugarcane on Pahokee muck soil.

Treatment	Fertilizer rate <sup>1</sup>	
	Phosphorous (P)	Potassium (K)
	-----kg/ha-----	
Control	0	0
Low	0	305
Medium	20	375
High	69	515

<sup>1</sup> Sources: triple superphosphate (46% P<sub>2</sub>O<sub>5</sub>), muriate of potash (60% K<sub>2</sub>O).

The plots were planted on 17 January, 1985 using variety CL 61-620. The seed pieces were placed in the furrow on top of the fertilizer band and then covered with a three-row covering rig. The distance of the fertilizer band from the soil surface after covering was 12-15 cm. Crop cultivation was done according to the commercial production practices of the grower. Soil samples of the control plot were taken at planting and at harvest on 4 February, 1986. The soil was sampled through the row in 15 cm increments to a depth of 90 cm using a soil auger which had an internal diameter of 7.5 cm. The barrel of the auger had a volume of 650 ml so it was only necessary to take one core through the plot to obtain enough soil for testing of each 15 cm increment. The fertilized plots were sampled on 5 February, 1986 in 15 cm increments to a depth of 75 cm. Three cores were taken in each plot at a distance of 0, 38, and 76 cm from the row which represents values of 0, 25, and 50% of the distance from the sampled row to the adjacent row. Laboratory analysis of the soil was performed on air-dried samples according to methods developed specifically for Everglades Histosols (9).

## RESULTS AND DISCUSSION

Two trends which were associated with soil depth were observed but were not related to fertilizer treatments. There was a tendency for the pH and extractable sodium levels to increase with sampling depth in the control plot (Table 2). This was true also for all of the cores which were taken for the fertilized plots at harvest (data not shown). In a study using the same soil type, Lucas (6) did not show a correlation between pH and depth for two locations sampled in increments from 0 to 60 cm. It seems reasonable to assume that the limestone bedrock which underlies most Everglades Histosols will exert an influence on the pH of the soil above it especially during periods when the water table is maintained above the rock. Apparently the distance between the deepest sample taken and the surface of the bedrock was too great in the Lucas study to show an influence on the soil pH.

Working with a Pahokee muck soil which had been cropped in celery for over 20 years, Baligar *et al.* (1) found that sodium occupied in excess of 7.0% of the exchange sites. In addition, it was shown that sodium accounted for approximately 40% of the cations in solution. They did not discuss the possible source of sodium found in this soil although it was stated that summer fallow flooding was a standard practice for this field. Since the soil test values for sodium in my study were found to increase with depth, it is probable that sodium is a component of the water used for seepage irrigation. Upward capillary movement of water containing dissolved salts would account for the sodium observed in the upper region of the profile.

Soil samples taken in the control plot immediately prior to planting showed that the available potassium level was highest in the layer located 15-30 cm below the soil surface (Table 2). A possible explanation for a concentrated zone of potassium to occur below the surface layer of soil is that it represents the result of



downward movement from surface-applied fertilizer for previous ratoon crops. Lucas (6) found that most of the potassium which had been applied at the surface was located in the 6-15 cm layer of soil following 122 cm of rainfall which occurred during a 210 day period.

Table 2. Soil sampling results for control plot.

Depth	pH		Chemical content					
	1 <sup>1</sup>	2	P		K		Na	
			1	2	1	2	1	2
cm	-----kg/ha-----							
0-15	6.4	6.4	3.4	5.6	54	54	27	38
50-30	6.5	6.4	5.6	4.5	152	3	50	38
30-45	6.5	6.6	5.6	4.5	76	11	74	76
45-60	6.4	6.5	5.6	3.4	41	11	101	76
60-75	6.6	6.6	2.2	1.1	22	27	110	114
75-90	6.9	6.8	3.4	2.2	49	36	170	155

<sup>1</sup> Sampling dates: 1 = 17 January 1985; 2 = 4 February 1986.

Lateral movement of phosphorus was not detected by the sampling scheme used for this study (Table 3). For the highest rate of applied phosphorus, the phosphorus values at all soil depths for the core taken 38 cm from the fertilizer band were similar to the corresponding values where no P was applied. In contrast, the phosphorus values in the upper 45 cm of soil for samples taken through the row were substantially higher than the values for these layers at a distance of 38 or 76 cm from the row. Clayton *et al.* (2) concluded that the rate of vertical seepage through Everglades Histosols is much greater than in the horizontal direction due to the vertical orientation of sawgrass roots. Movement of water soluble ions would therefore be expected to be greater in the vertical rather than the lateral direction. The resistance of the surface layer of this type of soil to leach P is probably due to two factors: the presence of large amounts of exchangeable calcium and a significant sesquioxide content brought about by prolonged tillage as described by Larsen *et al.* for Indiana Histosols (5).

As was the case with phosphorus, the results do not indicate that there was lateral movement of potassium (Table 3). The values of soil K at all depths and fertilizer rates for cores taken 38 or 76 cm from the row were similar to the corresponding results for the control plot at harvest (Table 2). Vertical movement of K into the 45-75 cm zone was indicated by consistently higher values in this area for samples below the fertilizer band versus corresponding values for samples taken at 38 and 76 cm from the row. For example, at the highest rate of K fertilization, the value for K in the 45-60 cm layer was 84 kg/ha while the values at this depth at a distance of 38 and 76 cm from the row were 8 and 11 kg/ha, respectively.

The highest values for both P and K were found in the 0-15 cm surface layer for all fertilized plots (Table 3). This was in spite of 131 cm of rainfall which occurred during the course of the experiment. Although this volume was 13 cm below the 60 year average (7), it is somewhat surprising that the values in the 0-15 cm zone were not lower. After all, the fertilizer P and K would have to move less than 5 cm from the original point of placement to be located in the 15-30 cm layer. As was noted earlier, the highest soil K value for the control plot prior to planting was found in the 15-30 cm depth. The persistence of potassium to remain near the point of placement could be due to an increase in the strength of binding sites associated with organic matter decomposition as proposed by Baligar *et al.* (1). In addition, potassium could move down following significant rainfall events and then up during prolonged dry periods. This explanation was offered by Gascho and Kidder (4) when they found seasonal fluctuations in soil potassium levels of control plots in two replicated sugarcane fertility experiments.



Table 3. Post harvest phosphorus and potassium soil test levels as affected by treatment and distance from fertilizer band.

Depth	Distance from row	Chemical content					
		Low <sup>1</sup>		Medium		High	
		P	K	P	K	P	K
cm	cm	-----kg/ha-----					
0-15	0	6.7	156	7.8	213	78.0	190
	38	5.6	41	4.5	60	3.3	27
	76	6.7	76	5.6	80	5.6	30
15-30	0	6.7	73	6.7	130	12.0	139
	38	4.5	11	4.5	11	4.5	22
	76	6.7	11	6.7	35	4.5	8
30-45	0	6.7	54	4.5	84	7.8	99
	38	6.7	11	6.7	11	4.5	11
	76	7.8	22	4.5	16	5.6	8
45-60	0	2.2	41	2.2	73	3.3	84
	38	2.2	11	2.2	3	2.2	8
	76	3.3	30	2.2	19	2.2	11
60-75	0	2.2	41	1.1	49	2.2	57
	38	1.1	11	2.2	3	2.2	11
	76	2.2	22	1.1	8	1.1	11

<sup>1</sup> See Table 1 for fertilizer rates.

## CONCLUSION

No lateral movement of phosphorus or potassium from the fertilizer band placed beneath the sugarcane seed piece could be detected at a distance of 38 cm from the row. There was evidence to support a finding of vertical mobility for both elements. The data indicated that the levels of phosphorus in the 15-45 cm zone below the fertilizer band containing the highest rate of applied P were larger than corresponding values at 38 and 76 cm from the row. Values for soil K were uniformly higher at all soil depths for samples taken below the fertilizer band versus samples taken 38 or 76 cm from the row. In spite of the apparent vertical movement of P and K, the values for soil P and K were highest in the uppermost layer of soil which contained the original band of fertilizer. Although researchers have acknowledged that higher soil test values could probably be found near a band of fertilizer for as long as one year after application (3), the significance of a concentrated zone of fertilizer in the middle of the root system of ratoon sugarcane crops has yet to be evaluated.

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# EFFECTIVE DISTANCE OF NUTRIENT ACQUISITION FOR SUGARCANE GROWN ON EVERGLADES HISTOSOLS<sup>1</sup>

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Belle Glade, Florida

## ABSTRACT

Over 158,000 ha (89.9%) of the sugarcane produced in Florida is grown on Histosols (organic soils). Over the years, sugarcane fertility trial results have been erratic and variable. The objectives of this research were to use an <sup>15</sup>N-tracer to define the effective distance of nutrient acquisition for sugarcane and to gather preliminary data on the degree of lateral movement of mobile fertilizer nutrients through an organic soil. It was hypothesized that interactions between distance of <sup>15</sup>N acquisition and crop age, sampling direction, and sampling distance could be explained by sugarcane root system morphology. A significant <sup>15</sup>N label accumulated in the top visible dewlap leaf tissue collected from plants growing 3.75 and 2.25 m from the tracer source for a plant-cane and 1st-ratoon crop, respectively. Based on conventional 1.5 m row spacing, 3-row and 2-row borders surrounding the data collection area must be maintained in order to completely prevent inter-plot interference on nutrient acquisition for plant-cane and 1st-stubble experiments, respectively. Over time, the <sup>15</sup>N tracer did not move laterally through the soil more than 0.75 m from the source. Additional research is needed to accurately describe fertilizer nutrient movement through organic soils.

## INTRODUCTION

Over 158,000 ha (89.9%) of the sugarcane produced in Florida is grown on Histosols (organic soils) (3). These organic soils are highly productive and fertilizer amendments are required for optimum productivity. Gascho and Kidder (4) developed the current fertilizer recommendations for sugarcane grown on Histosols in the Everglades Agricultural Area (EAA) and noted that there were large differences in fertilizer use efficiencies, and soil-test and crop responses to applied fertilizers, among different organic soil types. They also noted erratic and variable soil-test and crop responses within study locations. These inconsistencies have since been observed in numerous sugarcane fertility trials throughout the EAA. In order to update and refine fertilizer recommendations, researchers must attempt to define and limit the naturally occurring and experiment imposed error factors that contribute to the variability present in sugarcane fertility trials.

Recently, attention has been focused on the nutrient content (especially N and P) of drainage waters from Florida sugarcane fields. Early researchers recognized that high rates of P fertilizers were detrimental to sugar production (1,7,8,9). Now it is apparent that excessive application of fertilizers may not only hinder sugar production but may also be detrimental to the quality of drainage water.

This research was conducted to gather information on two related problems. The seemingly inherent variability associated with sugarcane fertility trials may be partially attributed to improper experiment design. Inadequate plot border area may result in inter-plot interference with respect to applied fertilizer treatments. This plot-to-plot contamination may be due to root proliferation of plants from one plot into an adjacent plot or lateral movement of applied fertilizers through the soil, by mass flow and diffusion through the soil solution. Experiments using <sup>15</sup>N-tracer techniques have been conducted to study the fate and efficacy of applied N fertilizers for sugarcane grown on mineral soils (2,13,14,15,16) and to establish fertility research plot size requirements for other crops (6,10,12). The use of <sup>15</sup>N-tracers in sugarcane grown on organic soils has not been reported.

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The first objective of this research was to use a  $^{15}\text{N}$ -tracer to define the effective area of nutrient acquisition and the minimum plot border size required for sugarcane fertility trials on organic soils. The second objective was to gather preliminary data on the degree of lateral movement of mobile fertilizer nutrients through an organic soil.

## MATERIALS AND METHODS

This study was conducted simultaneously in two adjacent commercial sugarcane fields in Palm Beach County, Florida. The soil type of both fields was Pahokee muck (euic, hyperthermic Lithic Medisaprist). Both fields were planted to cultivar CP72-1210. One field was in plant cane (planted 14 December 1987) and the other field was in first-ratoon cane (planted 8 November 1986, plant cane harvested 2 December 1987). On 30 June 1988, a randomized complete block experiment with 4 replications was established in both the plant-cane and the 1st-ratoon field. To serve as a tracer source, 140 g of  $^{15}\text{N}$ -enriched  $\text{NH}_4\text{NO}_3$  (3% enrichment) was applied in a subsurface band (4 m long, 5 cm wide) buried 3 cm beneath the soil surface midway between two rows of sugarcane planted on 1.5 m row spacing. Plant tissue was sampled 13, 27, 42, 55, and 139 days after  $^{15}\text{N}$  application. Five top visible dewlap (TVD) leaves were collected parallel to the  $^{15}\text{N}$  band, from the 1st through 5th rows (0.75, 2.25, 3.75, 5.25, and 6.75 m, respectively) on both sides of the  $^{15}\text{N}$  band. Five TVD leaves were also collected from the 15th row (21.75 m) on both sides of the  $^{15}\text{N}$  band. This 15th-row sample location was assumed to approximate a relatively infinite distance from the  $^{15}\text{N}$  band and served as the control for the plot. Figure 1 is a diagram of a single replicate. Leaf samples from corresponding rows on either side of the  $^{15}\text{N}$  band were combined resulting in one 10-leaf sample for each sampling distance. Five TVD leaves were also collected along the two rows adjacent to the  $^{15}\text{N}$  band at 0.75, 2.25, and 3.75 m from both ends of the band (Figure 1). All leaf tissue was dried ( $60^\circ\text{C}$ ) and ground to pass through a 0.85 mm screen. Soil samples (0-15 m depth) were taken 139 days after  $^{15}\text{N}$  application at locations corresponding to each TVD leaf sample location (Figure 1). All leaf tissue and soil were analyzed for atom %  $^{15}\text{N}$  by mass spectroscopy (5). Percent excess  $^{15}\text{N}$  was calculated as follows:

$$\frac{(\text{atom } \% ^{15}\text{N sample}) - (\text{atom } \% ^{15}\text{N control})}{\text{atom } \% ^{15}\text{N control}} \times 100$$

The average atom %  $^{15}\text{N}$  control over all samples was 0.370 (SE=0.001). Analyses of variance of the data were performed using SAS PROC GLM procedures (11). Sampling date means were separated by Waller-Duncan K-ratio T-test mean separation procedures (11).

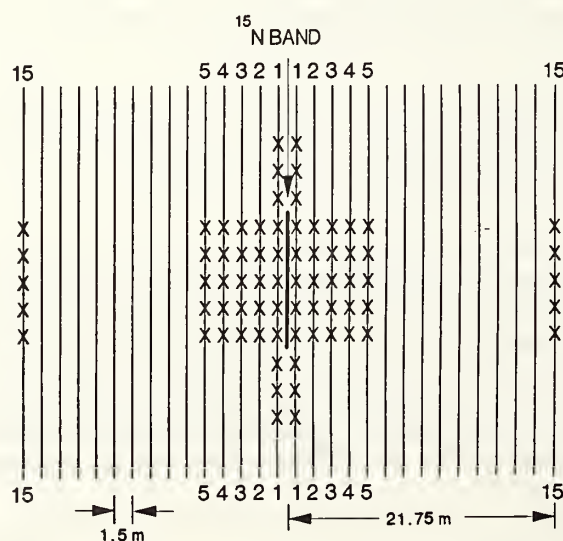


Figure 1. Field plot design and sampling pattern for a single replicate. "X" denotes sampling location.



## RESULTS AND DISCUSSION

Sugarcane plants may acquire  $^{15}\text{N}$  from the tracer source by root proliferation into the labeled soil zone and/or by lateral movement of the  $^{15}\text{N}$  through the soil into the root zone of the plant. Nutrient movement laterally through the soil should not be different between the plant-cane and 1st-ratoon crops which were in adjacent fields with very similar soil and environmental characteristics. When averaged over the 5 sampling dates, the 1st-ratoon crop had a significantly greater  $^{15}\text{N}$  label in the TVD leaf tissue at the 0.75 m sampling distance than the plant-cane crop (Table 1). In contrast, at 2.25 and 3.75 m from the  $^{15}\text{N}$  tracer source, the plant-cane crop had a significantly greater TVD  $^{15}\text{N}$  label.

Table 1. Effect of crop age and sampling direction on effective distance of  $^{15}\text{N}$  acquisition by sugarcane. Means are the average of 5 sampling dates. Crop age and sampling direction means were calculated over sampling directions and crop ages, respectively.

Sampling distance	Crop age				Sampling direction					
	Plant cane		1st ratoon		Across rows		Along rows			
m	-----% excess <sup>15</sup> N-----									
0.75	14.5	(13.2)†	*	20.7	(21.8)	25.0	(18.9)	**	5.1	(4.1)
2.25	0.9	(1.2)	**	0.2	(0.5)	0.7	(1.2)	*	0.3	(0.6)
3.75	0.2	(0.5)	*	0.0	(0.4)	0.1	(0.5)		0.1	(0.3)
5.25	0.1	(0.1)		0.0	(0.3)	0.0	(0.2)		---	---
6.75	0.0	(0.1)		0.0	(0.2)	0.0	(0.2)		---	---

\*\*, \* Crop age or sampling direction means within a sampling distance are significantly different at  $P < 0.01$  and  $0.05$ , respectively.

† Value in brackets is standard error of the mean.

Based on data in Table 1, it can be hypothesized that, at similar stages of crop development, the 1st-ratoon crop had a greater concentration of active roots near the stool than the plant-cane crop. This greater functional root density around the base of the 1st-ratoon plant may be the result of root regrowth from axillary buds near the stool, corresponding to ratoon tiller regrowth above ground. It is further proposed that, at similar stages of crop development, the plant-cane crop had a more extensive active root system, although not as dense near the stool, which explored a larger soil volume than the 1st-ratoon crop and therefore acquired the  $^{15}\text{N}$  label at a greater distance from the tracer source.

Of the two modes of nutrient acquisition discussed above, lateral movement of  $^{15}\text{N}$  through the soil should not be influenced by row orientation relative to the tracer source band. For both crops, the TVD leaves collected at 0.75 and 2.25 m across rows had significantly greater  $^{15}\text{N}$  labels than those collected along rows (Table 1). Intrarow competition among adjacent plants may have promoted preferential root exploration of the interrow space and resulted in root system proliferation into the  $^{15}\text{N}$  labelled soil. Root system development across rows would expand the effective nutrient acquisition area in field-plot fertility studies beyond the planted plot boundary.

From Table 1, the effective distance of  $^{15}\text{N}$  acquisition for sugarcane grown on organic soil can be defined. For a plant-cane crop, a TVD  $^{15}\text{N}$  label significantly greater than zero was observed 3.75 m from the tracer source. Based on conventional 1.5 m row spacing, a 3-row border surrounding the data collection area must be maintained in order to completely prevent potential inter-plot influences on nutrient acquisition. For a 1st-ratoon crop, a significant  $^{15}\text{N}$  label was observed 2.25 m from the source. Accumulation at this level necessitates a 2-row border be maintained during 1st-ratoon crop fertility trials in order to completely isolate the fertilizer treatment. For the plant-cane and 1st-ratoon crops, the TVD  $^{15}\text{N}$  labels at 2.25 m from the tracer

source were only 6% and 1%, respectively, of the TVD  $^{15}\text{N}$  label at the 0.75 m sampling position. If this level of inter-plot interference is tolerable, then a single border row would be sufficient for fertility trials.

Across both crops and sampling directions, the pattern of  $^{15}\text{N}$  accumulation in TVD leaf tissue did not change markedly over time (Figure 2). There were significant differences in percent excess  $^{15}\text{N}$  among sampling dates (Day 42 > Day 13 = Day 27) at the 0.75 m distance. At 2.25 m and beyond, TVD percent excess  $^{15}\text{N}$  was not significantly different among sampling dates.

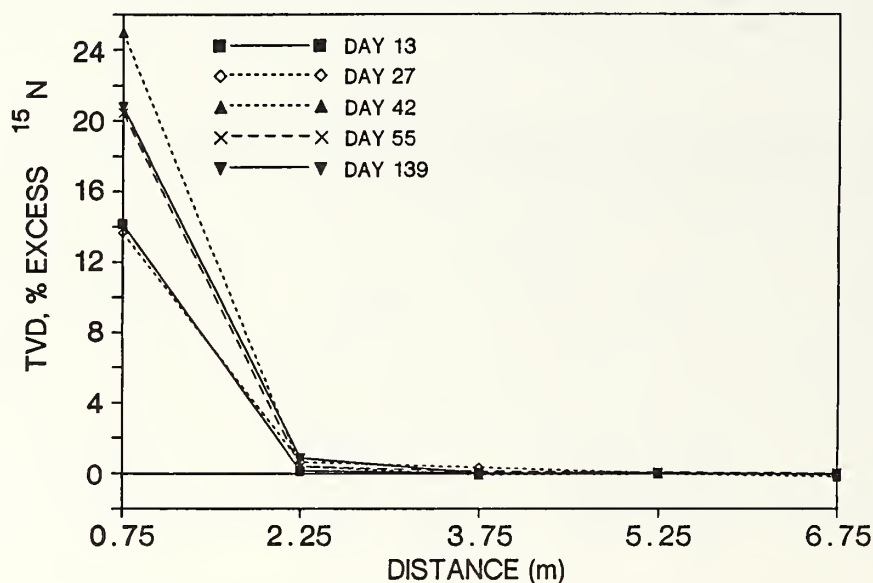


Figure 2. Effect of distance from tracer source on percent excess  $^{15}\text{N}$  in TVD leaf tissue at 5 time intervals after  $^{15}\text{N}$  application

At 139 days after tracer application, there was a significant  $^{15}\text{N}$  label in the surface soil (0-15 cm deep) collected 0.75 m across rows from the source band (Figure 3). There were no significant  $^{15}\text{N}$  labelled soil samples collected beyond 0.75 m. Also, there was no detectable movement of the tracer through the surface soil along rows.

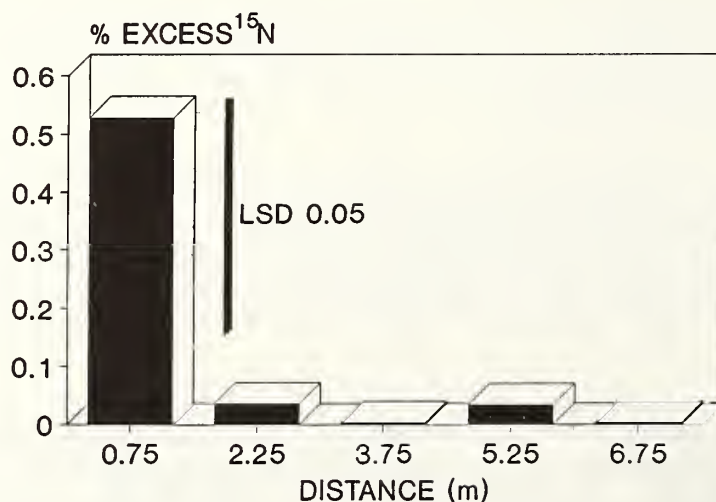


Figure 3. Effect of sampling distance across rows on soil percent excess  $^{15}\text{N}$  measured 139 days after application. Means are averaged across crops.

By 50 days after  $^{15}\text{N}$  application, the experiment had been inundated by over 40 cm of rainfall (Figure 4). For numerous days during this 50 day period, both fields were flooded with up to 8 cm of water. Even with this excess surface water, which eventually percolated through the soil profile, the  $^{15}\text{N}$  tracer did not move laterally through the soil more than 0.75 m from the source.

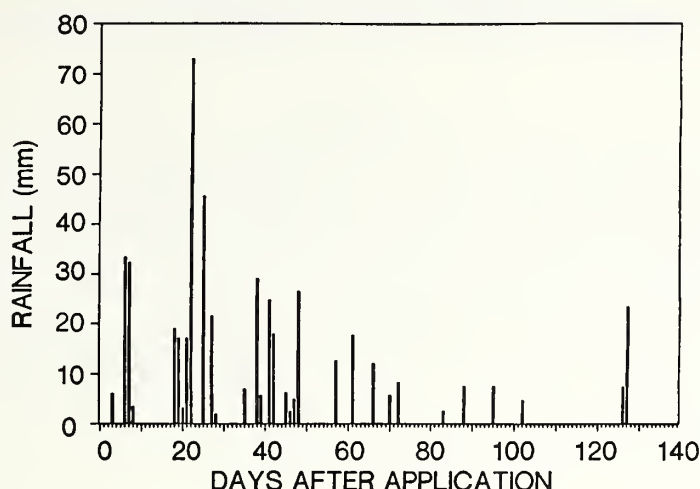


Figure 4. Rainfall distribution over the sampling period.

Nitrogen is considered a highly mobile fertilizer nutrient and naturally mineralized N is abundantly available in organic soil. Therefore, the mobility of  $^{15}\text{N}$ -labelled fertilizer through organic soil has been evaluated under a "worst case condition" and lateral movement was found to be very limited. Additional research is necessary to accurately describe the lateral movement of various fertilizer nutrients through organic soils.

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# FUNGICIDAL CONTROL OF PINEAPPLE DISEASE OF SUGARCANE

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## ABSTRACT

Fungicidal treatments of sugarcane seedpieces were evaluated for control of pineapple disease on the organic soils of the Everglades Agricultural Area in Florida. Two methods of fungicide delivery, a seedpiece dip at ambient temperature and an in-furrow spray application, were investigated under both field and greenhouse conditions using the fungicide propiconazole. Results indicated that under conditions favorable for disease development, both methods significantly increased shoot emergence when compared to controls. However, dip applications appeared to be more effective than in-furrow sprays. Dip applications with benomyl, thiophanate methyl, flusilazole, and ethyltrianol also provided significant levels of control in a greenhouse experiment.

## INTRODUCTION

Pineapple disease, caused by the fungus *Ceratocystis paradoxa* (Dade) C. Moreau, is an important factor affecting establishment of new sugarcane stands (interspecific hybrids of *Saccharum*) in many areas of the world (16). The most serious losses are through the failure of infected cuttings to germinate (4), although standing cane may also become infected (5, 8). Although pineapple disease has been reported in Florida (1), very little is known about its distribution or impact on Florida sugarcane production. A greenhouse study examining cultivar susceptibility indicated that at least two Florida cultivars, CP 74-2005 and CP 72-2086, are very susceptible (9). These results corroborate observations of poor stands of these particular cultivars when exposed to cool wet soil conditions in commercial fields. Along with frequent direct isolation of *C. paradoxa* from nongerminated seedpieces, these observations suggest that pineapple disease, under favorable conditions, may play a significant role in stand establishment of certain Florida cultivars.

Recommended control measures for pineapple disease include the use of resistant cultivars (15), avoidance of factors leading to slow seedpiece germination (12), and fungicidal treatment of seedpieces (4, 6, 11). In Australia, where cane is mechanically planted using cutter-planters, seedpieces or setts are routinely sprayed with a fungicide as part of the planting operation (13, 14). In other areas of the world, fungicides are applied as a seedpiece dip, often in combination with a hot water treatment used for stimulating germination and control of ratoon stunt disease (2,4).

The objectives of these investigations were two-fold: 1) to evaluate the efficacy of fungicides for control of pineapple disease under Florida growing conditions, and 2) to compare the efficacy of two methods of fungicide application. A preliminary report has been published (10).

## MATERIALS AND METHODS

Experiments were conducted during 1988 and 1989 at the Everglades Research and Education Center at Belle Glade, Florida. Cultivar CP 74-2005, which has demonstrated susceptibility to pineapple disease (9), was used in all experiments.

### Experiment 1

Propiconazole (1-[[2-(2,4-dichloro-phenyl)-4-propyl-1,3-dioxolan-2-yl]methyl]-1H-1,2,4-triazole), a fungicide, and cytochrome (cytokinin), a plant growth regulator, were evaluated for the control of pineapple disease. The growth regulator was used in an attempt to promote rapid germination, thereby reducing the effects of the disease. Sugarcane was planted in a 0.3 ha field plot on 8 Jan, 1988. Soil was classified as 'Pahokee muck' with a pH of 6.2 and was fertilized according to soil test recommendations. The field site was selected specifically for its poor drainage and sugarcane production history. Cane was planted as single lines of seedpieces in rows

with 1.5 m spacing. Seedpieces were 45 to 60 cm in length with approximately four to six nodes per piece. Seedpiece treatments consisted of a nontreated check, a 5 min seedpiece dip in a propiconazole suspension (45 ppm ai) at ambient temperature, a banded (15-cm-width) propiconazole spray (0.21 kg ai/ha) in the furrow prior to covering, and a banded cytozen spray (1.7 l prod/ha) in the furrow prior to covering. In-furrow sprays were applied with a CO<sub>2</sub> backpack sprayer in 187 l of water/ha with a flat-fan nozzle at 138 kPa. Rows were covered following treatment with a tractor-mounted covering rig. Treatments were arranged in randomized complete blocks in a split-plot design with six replications. Main plots were artificially-infested with inoculum of *C. paradoxa* or were not artificially-infested. Inoculum consisted of 7-10 cm quartered sections of sugarcane stalks that had been inoculated with a spore suspension and incubated at room temperature for one week, after which they were observed to support abundant sporulation. All sections containing nodes were discarded to avoid future germination. Pieces of inoculum were placed in the planting furrow at approximately 30-cm-intervals prior to covering. Treatment subplots consisted of three rows 12.1 m in length. Primary shoot counts were made on 17 Feb, 4 Mar, and 23 Mar. Harvestable stalk counts were made on 19 Sept. Yield estimates were obtained from stalk samples (20 stalks/subplot) cut and milled on 2 Mar, 1989.

### Experiment 2

Nine different fungicide treatments were compared to inoculated and noninoculated checks for control of pineapple disease in an experiment conducted in the greenhouse. Five treatments consisted of a fungicide applied as a seedpiece dip at ambient temperature. Fungicides tested as dips were propiconazole, benomyl ([Methyl 1-(butylcarbamoyl)-2-benzimidazole carbamate]), thiophanate methyl (dimethyl[1,2-phenylene]-bis(iminocarbonothioyl)]bis[carbamate]), flusilazole (1-[[Bis(4-fluorophenyl) methylsilyl] methyl] -1H-1,2,4-triazole), and ethyltrianol ([2-(4-Chlorophenyl)ethyl]-(1,1-dimethylethyl)-1H-1,2,4-triazole-1-ethanol). Suspension concentrations used in the experiment (Table 2) were those recommended by the manufacturer or those reported as efficacious by other investigators (3, 4, 7). Four treatments consisted of propiconazole applied at various rates (0.126, 0.186, and 0.252 kg ai/ha) using a simulated in-furrow spray application. Sprays were applied in 187 l of water/ha with a flat-fan nozzle at 138 kPa, with the exception of a second 0.252 kg ai/ha propiconazole treatment, which was applied in 374 l of water/ha. All sprays were initiated and terminated outside the flats to ensure accurate application. Twenty-five single-node seedpieces 10 cm in length were planted per treatment flat in organic soil (Pahokee muck, pH 6.0) containing  $1 \times 10^4$  conidia/gram of soil (air-dried wt.) or in fumigated organic soil (uninoculated check). Seedpieces were cut so the node was equidistant (5 cm) from each end. Treatments were arranged in randomized complete blocks with four replications.

### Experiment 3

Fungicide treatments previously described in Experiment 2 were tested for efficacy under natural field conditions. Sugarcane was planted in a 0.2 ha field plot on 19 Oct 1988. Soil was classified as "Pahokee muck" with a pH of 6.0 and was fertilized according to soil test recommendations. Treatment subplots consisted of single rows of 45-60 cm seedpieces and were arranged in randomized complete blocks with seven replications. Subplots were 10.7 m in length. The number of nodes per subplot was recorded prior to closing of seedpiece furrows for subsequent calculations of percent emergence. Primary shoot counts were performed on 4 Jan, 1989.

## RESULTS AND DISCUSSION

### Experiment 1

Results of the experiment investigating two methods of propiconazole application and cytozen application on emergence are presented in Table 1. Heavy rains and cool temperatures subsequent to planting created ideal conditions for pineapple disease development. Excavation of nongerminated seedpieces and subsequent isolations showed the disease to be the primary reason for lack of germination. Severe pineapple disease development in guard rows and in main plots not receiving artificial inoculum indicated that natural *C. paradoxa* inoculum was present throughout the field plots. This obscured any influence by the artificial inoculation. Statistical analyses indicated no significant main plot effects ( $P \leq 0.05$ ) and therefore data were merged for further analyses. Propiconazole applied as either a dip or as an in-furrow spray resulted in a significant increase in number of primary shoots over the nontreated check, with the dip application being superior to the in-furrow spray at the rates tested. Emergence in the cytozen treatment was not significantly different from that in the control. Propiconazole treatments resulted in significant increases in number of millable stalks (Table 1), cane yield per unit area, and total sugar yield per unit area (Table 2). Average stalk weight was less in the propiconazole dip



treatment than in the nontreated check, while average stalk density was greater. This result may be explained by the increased competition for nutrients and light. One of these factors may have become limiting. Differences in sugar per unit of cane were not significant among treatments.

Table 1. Effect of seedpiece treatments on emergence and millable stalk populations of cultivar CP 74-2005 in a field experiment conducted in Belle Glade, Florida, during 1988-1989.

Treatment	Method <sup>1</sup>	Rate	Number of primary shoots <sup>2</sup>			# Stalks <sup>3</sup>
			2-17-88	3-4-88	3-23-88	
Nontreated check	---	---	1.3 c	4.3 c	6.6 c	39.9 d
Propiconazole	Dip	45 ppm	9.8 a	22.0 a	29.9 a	115.4 a
Propiconazole	Spray	0.21 kg ai/ha	5.1 b	13.1 b	17.8 b	84.9 b
Cytogen	Spray	1.7 l prod/ha	1.6 c	5.8 c	8.4 c	50.8 c

<sup>1</sup> Method of chemical treatment. Dip application consisted of a 5 min seedpiece dip in a suspension of the indicated concentration at ambient temperature. Sprays were applied as in-furrow directed (10-20 cm band) sprays applied with a CO<sub>2</sub> backpack sprayer in 187 l/ha of carrier at 138 kPa.

<sup>2</sup> Number of primary shoots emerged per 10.7 m of row on the indicated dates. The experiment was planted on 8 January 1988. Numbers followed by letters in common are not significantly different (Duncan's Multiple Range Test P = 0.05).

<sup>3</sup> Number of millable stalks present on 19 September 1988.

Table 2. Effect of seedpiece treatment on average stalk weight, cane per unit area, sugar per unit of cane, and sugar per unit area of cultivar CP 74-2005.<sup>1</sup>

Treatment	Method <sup>2</sup>	Rate	Mean stalk wt. (kg/stalk)	Cane per unit area (Mg/ha)	Sugar per unit cane (kg/Mg)	Sugar per unit area (kg/ha)
Nontreated check	---	---	2.08 a	50.3 c	122.5 a	6195 c
Propiconazole	Dip	45 ppm	1.96 b	139.6 a	125.6 a	17585 a
Propiconazole	Spray	0.21 kg ai/ha	2.02 ab	105.5 b	123.8 a	13099 b
Cytogen	Spray	1.7 l prod/ha	2.12 a	66.2 c	123.6 a	8244 c

<sup>1</sup> Means followed by letters in common are not significantly different (Duncan's Multiple Range Test P=0.05).

<sup>2</sup> Method of chemical treatment. Dip application consisted of a 5 min seedpiece dip in a suspension of the indicated concentration at ambient temperature. Sprays were applied as in-furrow directed (10-20 cm band) sprays applied with a CO<sub>2</sub> backpack sprayer in 187 l/ha of carrier at 138 kPa.

## Experiment 2

Results of the greenhouse fungicide experiment are presented in Table 3. Conditions for pineapple disease development were excellent, as demonstrated by the low percent emergence in the inoculated check (9%). All fungicide treatments provided significant levels ( $P \leq 0.05$ ) of control when compared to the inoculated check. All fungicide treatments performed as well as the nontreated check containing no inoculum. Efficacies exhibited by spray treatments suggest that this method of application demonstrates potential and deserves to be investigated more thoroughly.

Table 3. Effects of fungicide treatments on percent emergence of cultivar CP 74-2005 in a greenhouse test conducted in flats.

Treatment	Method <sup>1</sup>	Rate	Percent emergence <sup>2</sup>
Inoculated check	---	---	9 d
Nontreated check	---	---	59 abc
Benomyl	Dip	300 ppm	63 ab
Thiophanate methyl	Dip	422 ppm	49 bc
Flusilazole	Dip	25 ppm	47 c
Ethyltrianol	Dip	25 ppm	57 abc
Propiconazole	Dip	25 ppm	65 a
Propiconazole	Spray	126 g ai/ha	46 c
Propiconazole	Spray	186 g ai/ha	56 abc
Propiconazole	Spray	252 g ai/ha	46 c
Propiconazole	Spray	252 g ai/ha <sup>3</sup>	53 abc

<sup>1</sup> Method of chemical treatment. Dip application consisted of a 5 min seedpiece dip in a suspension of the indicated concentration at ambient temperature. Spray treatments consisted of in-furrow directed (10-20 cm band) sprays applied with a CO<sub>2</sub> backpack sprayer in 187 l/ha of carrier at 138 kPa.

<sup>2</sup> Percentage of buds successfully germinating and developing into a primary shoot. Means followed by letters in common are not significantly different (Fisher's Least Significance Difference Test  $P=0.05$ , LSD=14.4).

<sup>3</sup> Applied in 374 l of water/ha.

## Experiment 3

Results of the fungicide field experiment are presented in Table 4. Warm soil temperatures and abnormally dry fall weather created ideal conditions for sugarcane stand establishment, reducing the effects of pineapple disease development. Although mean percent emergence in the nontreated check was lower than in all the fungicide treatments, this difference was not always significant at the  $P \leq 0.05$  level. With respect to propiconazole treatments, emergence in the dip treatment was significantly higher than in the spray treatments with the exception of the 252 g ai/ha treatment applied in 374 l of water/ha.



Table 4. Effects of seedpiece treatments on percent emergence of cultivar CP 74-2005 in a field experiment conducted during Fall, 1988.

Treatment	Method <sup>1</sup>	Rate	Percent emergence <sup>2</sup>
Nontreated check	---	---	27.3 d
Benomyl	Dip	300 ppm	33.4 abcd
Thiophanate methyl	Dip	422 ppm	35.6 ab
Flusilazole	Dip	25 ppm	33.3 abcd
Ethyltrianol	Dip	25 ppm	34.6 abc
Propiconazole	Dip	25 ppm	36.9 a
Propiconazole	Spray	126 g ai/ha	30.1 bcd
Propiconazole	Spray	186 g ai/ha	29.9 bcd
Propiconazole	Spray	252 g ai/ha	28.6 cd
Propiconazole	Spray	252 g ai/ha <sup>3</sup>	34.3 abc

<sup>1</sup> Method of chemical treatment. Dip application consisted of a 5 min seedpiece dip in a suspension of the indicated concentration at ambient temperature. Spray treatments consisted of directed sprays (20 cm band width) applied with a CO<sub>2</sub> backpack sprayer in 187 l/ha of carrier at 138 kPa.

<sup>2</sup> Percentage of buds successfully germinating and developing into a primary shoot. Means followed by letters in common are not significantly different (Fisher's Least Significance Difference Test P=0.05, LSD=6.40.)

<sup>3</sup> Applied in 374 l of water/ha.

## CONCLUSIONS

Under conditions favorable for pineapple disease development, application of fungicides to sugarcane seedpieces significantly improved shoot emergence. These results corroborate those reported in other sugarcane producing areas and demonstrate that on the organic soils of the Everglades Agricultural Area, chemical control appears to be a viable management procedure. Overall, dip application appeared to be more effective than the in-furrow spray applications tested; although, differences were not always significant. In-furrow sprays, however, did show some promise. Pineapple disease infections normally originate at the ends of a seedpiece, so delivery of the fungicide to this area could be critical, despite the systemic nature of the fungicides tested. Future research should concentrate on application techniques for improving fungicidal coverage of this area.

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## REGULATION OF SET-ROOT GERMINATION IN SUGAR CANE SEED PIECES

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### ABSTRACT

Studies were conducted with excised, sugarcane single-node sets taken from NCo 310 to identify regulatory mechanisms controlling the germination of set-root primordia incubated at 30° C. Set-root germination was inhibited in the presence of light but readily occurred in a moisture-saturated chamber protected from light. Direct contact with water was not necessary for germination. Set-root germination of complete and bud-free single-node sets incubated in the light was not increased by treatment with ethylene, indole-3-acetic acid, indolebutyric acid, kinetin, gibberellic acid, and abscisic acid. Abscisic acid, however, inhibited root germination in the dark. Set-root germination was unaffected by removal of the bud. Both abscisic acid and indole-3-acetic acid were present in the set tissue. Abscisic acid may act as a chemical mediator for the light inhibition of set-root germination in seed pieces from NCo 310.

### INTRODUCTION

The full germination of sugarcane seed pieces (sets) requires not only bud growth but also development and elongation of the adventitious root primordia circling the node. Set roots are essential for shoot growth until the new root system develops. Light, set moisture, soil moisture, temperature, bud maturity, set orientation, genetic composition, and size of the cutting of billet can influence bud and root germination (2, 10, 11, 13). In addition to environmental and genetic influences, auxin is implicated in the regulation of set germination (4, 12). Most of the studies to date have focused on growth of the new shoot and offer little information regarding set-roots. Whiteman et al. (13) reported that photoperiod and temperature influenced the early shoot and root growth of germinated sets but the effect of light on initial events associated with germination was not investigated. Light-imposed restriction of set-root germination has been observed in sugarcane (Benda, personal communication). Set-root germination in sugarcane and sorghum was apparently inhibited by incubating the multinode cuttings in an upright position (12). Localized applications of auxin to these cuttings reversed the inhibition of root germination; however, the most common naturally occurring auxin, indole-3-acetic acid (IAA), has not been analytically identified in sugarcane.

Light inhibits root growth in many crop plants including rice, corn, peas, and beans (7). The photo-inhibition of root growth may result from an accumulation of growth-inhibiting substances such as the plant hormone, abscisic acid (ABA). The inhibition of corn root elongation by light is related to a progressive accumulation of ABA (9). The photo-inhibition of lateral root development as well as the relationship of root development to endogenous plant hormones is poorly understood. A study was initiated to examine the effects of light, moisture, and exogenous plant hormones on set root germination and to identify the presence of ABA and IAA in sugarcane nodes.

### MATERIALS AND METHODS

Healthy stalks from NCo 310 were harvested from the Texas Agricultural Experiment Station farm near Weslaco, Texas. The stalks were transported to the laboratory, stripped of leaf blades and sheaths, and cut into billets of three or four nodes. The billets were sterilized by submersion in a 30% (V/V) solution of commercial bleach and distilled water for 30 minutes followed by continuous rinsing for five minutes in tap water. The billets were air dried for one hour and single node sets were removed with approximately 1 cm of tissue on either side

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<sup>1</sup>Work conducted while employed by USDA-ARS, Weslaco, Texas.



of the leaf scar. These sets containing intact root primordia and buds were used in the germination experiments. Bud-free nodes were prepared for some experiments by removing the bud and a minimal amount of associated tissue.

**Light experiments.** Sets were placed in containers with deionized water (3 mm depth) or on moistened pads of paper toweling. The sets were either horizontal, with the root band in contact with water or toweling, or vertical, with only the cut edge of one end in contact with water. Sets were placed in petri dishes covered by plastic bags and incubated on the laboratory bench (10  $\mu$ mol fluorescent light) or inside light proof cabinets.

In experiments to determine the effect of light quality, cylindrical cages were constructed from PVC pipe and covered with blue, green, yellow, red, black, and clear plastic wrap to alter the spectrum of light reaching the nodal samples. Panels were cut in the pipe leaving only a supporting framework to insure transmission of sufficient light to the set. Frames covered with the plastic were placed over individual sets, and the sets were incubated on the laboratory bench or in incubators at 30 ° C with 14 hr light periods. Light intensity was measured at 12 to 352  $\mu$ E s<sup>-1</sup> m<sup>-2</sup>.

**Moisture and orientation.** Complete sets were germinated in a vertical or horizontal position by suspending the nodal section on a wire frame in a 350 ml plastic box sealed with a lid and wax film wrap. The container and node were placed in the dark and incubated at room temperature (22 ° C) in direct contact with the moistened pad or suspended in the moisture-saturated chamber. Treatments were compared to controls incubated without external moisture.

**Hormone treatments.** The bud-free sets were horizontally positioned in polystyrene weighing boats with 10 ml of the hormone solution. Treatment of complete sets with bud and root primordia were conducted by vertically positioning the set with the basal end in contact with the hormone solutions. All sets, vertical or horizontal, were then placed in a 3.8-liter plastic freezer bag, sealed, and incubated in the light or dark at 30 ° C for 5 to 7 days. Hormone treatments were conducted with 10<sup>-5</sup>, 10<sup>-4</sup> and 10<sup>-3</sup> molar gibberellic acid, IAA, indolebutyric acid, kinetin, and ABA dissolved in distilled water. An ethylene treatment of 10 ppm was tested by injecting the appropriate amount of ethylene gas into the sealed, plastic freezer bag containing the sample set.

**Hormone analysis.** ABA and IAA were analyzed on a Hewlett Packard 5970B<sup>2</sup> gas chromatograph - mass spectrometer as described by Dunlap and Guinn (6). Freeze-dried tissue was homogenized and extracted with 70% (V/V) aqueous acetone. The extract was evaporated to the aqueous phase and divided into equal fractions for determination of free and bound forms of either hormone. The fraction analyzed for bound forms was subjected to alkaline hydrolysis (3, 5). The fraction containing free forms and the hydrolyzed fractions were purified by microfiltration, preparative chromatography on C18 SepPak (Waters, Milford, MA)<sup>2</sup>, and solvent partitioning (G. Guinn, USDA-ARS, Phoenix, AZ, personal communication). The resulting purified samples were methylated with diazomethane for analysis by GC-MS. Inner cores of tissue were removed from intact nodes for analysis in addition to the intact nodes.

## RESULTS AND DISCUSSION

The light-inhibited growth of set-root primordia was not affected by any of the colored plastics used as a filter (data not presented). The root primordia only germinated in the dark. However, bud germination was unaffected by light and germinated equally well in the light and dark. Set-root germination in the dark was unaffected by removal of the associated bud from the node (Table 1). The reduction in total number of roots in bud-free sets resulted from removal of root primordia adjacent to the bud. Set-roots on bud-free sets also failed to germinate in the light; therefore, this response to light is not dependent on the nearby bud.

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<sup>2</sup>Mention of a proprietary product does not constitute endorsement by the Texas A&M University System.



Table 1. The effect of bud removal on the germination of single sets of sugarcane incubated at 30° C in the light or dark for five to seven days. Mean  $\pm$  one standard deviation.

Treatment	Bud germination (%)		No. of roots	
	Light	Dark	Light	Dark
Intact bud	100	100	0	38 $\pm$ 7
Bud removed	--	--	0	17 $\pm$ 2

Although somewhat slow, complete germination of both buds and roots occurred when sets were suspended in moisture-saturated chambers (data not presented). Sets positioned in a vertical or horizontal position displayed equal capacity for full germination when incubated in the dark. Consequently, contact with water and position of set pieces are not limiting to set-root germination in the light.

In an attempt to identify hormonal mechanisms regulating set-root germination, sets were treated with an array of plant hormones followed by incubation in the light or dark. None of the hormone treatments promoted set-root germination in the light (data not presented). Auxin has been reported capable of promoting set-root germination (4, 12). Set-root germination in the dark, however, was unaffected by all hormone treatments except ABA. Absciscic acid consistently inhibited the dark germination of set root primordia in both complete and bud-free sets. Set-root germination was totally inhibited at a concentration of 1 mM ABA and partially suppressed at 0.1 mM (Table 2). Although some germination of root primordia took place at 0.1 mM ABA, root elongation was inhibited resulting in a reduced number of severely stunted roots.

Table 2. The effect of ABA on the number of developing roots for bud-free, single sets of sugarcane incubated in the dark at 30° C for five to seven days. Mean  $\pm$  one standard deviation.

ABA concentration (mM)	No. of roots
0.0	19 $\pm$ 5
0.1	9 $\pm$ 3
1.0	0

Since ABA inhibited germination, sets were analyzed to determine the presence of naturally occurring ABA. Using GC-MS analytical techniques, both ABA and IAA were identified in tissue from complete sugarcane sets with intact buds and root primordia. The free or acidic form of ABA, also considered to be an active form, was found at similar concentrations in complete sets and tissue isolated from the interior of the node (Table 3). The free form of IAA was also isolated and identified in the same tissue samples. The ester conjugates of ABA, considered to be inactive, were present in concentrations approximately five times greater than the free, active form. Levels of ABA in nodes were similar to those reported for leaves of well-watered sugarcane (8). Detectable levels of the IAA conjugates represented by the ester and amide forms were obtained from sugarcane set tissue. The concentrations of these IAA metabolites, however, were not as high as those determined for ABA. The IAA conjugates are considered to be a potential source of free IAA under certain conditions (1).

In summary, light inhibits the germination of set root primordia but does not influence bud germination. The bud is not required for the initiation of set-root germination in the dark. Therefore, the bud cannot be considered part of the regulatory mechanism controlling set root germination in sugarcane. Root germination can take place without direct contact with water and is independent of set orientation, i.e. horizontal or vertical positioning. Root germination was inhibited by light regardless of set orientation or available moisture.

Table 3. The cross-sectional distribution of the free and conjugated forms of ABA and IAA in single sets of sugarcane. Mean  $\pm$  one standard deviation.

Tissue segment	ABA (ng/g/dry wt)		IAA (ng/g/dry wt)		
	free	ester	free	ester	amide
Complete node	9 $\pm$ 5	46 $\pm$ 2	5 $\pm$ 1	15 $\pm$ 4	24 $\pm$ 11
Inner core	12 $\pm$ 4	49 $\pm$ 15	9 $\pm$ 3	1 $\pm$ 1	14 $\pm$ 1

Contrary to previous reports, we were unable to influence the normal germination responses to light or dark by treating sets with auxins or ethylene. In contrast to other hormone treatments in this study, ABA is a potent inhibitor of set-root germination in the dark. The ability to inhibit set-root germination in the dark makes ABA a potential mediator of the light effect on set-root germination in sugarcane. In addition to ABA, the natural plant auxin, IAA, was identified in sugarcane sets. Both hormones and their bound forms are distributed throughout the set tissue. The preliminary evidence suggests that metabolism regulating free ABA and IAA in other plant tissues may be operating in sugarcane sets. Efforts are underway to determine the effect of light on endogenous concentrations of ABA and IAA in sets of sugarcane. We expect the results from these additional experiments to clarify the role of ABA, and possibly IAA, in the light-inhibited germination of sugarcane set-roots.

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## EMERGENCE AND YIELD OF 2,4-D - TREATED SEED CANE <sup>1</sup>

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### ABSTRACT

Selected sugarcane (*Saccharum* interspecific hybrid) cultivars (first stubble) were treated with 2,4-D at 2.2 kg/ha in September, three and five weeks (1983) and five and seven weeks (1984) prior to harvesting for seed cane planting material. Sugarcane shoot populations in April and June the following year were generally reduced where 2,4-D was applied. Averaged across cultivars, millable stalk populations and yields of cane and sugar were reduced in 1984 an average of 23, 22, and 24%, respectively, but were not significantly affected in 1985. The greatest reductions in millable stalk populations and yields of cane and sugar were noted for CP 70-321 and CP 74-383 in 1984. Since the possibility of injury exists, late-season application of 2,4-D (three to seven weeks prior to harvest of seed cane) should be avoided.

### INTRODUCTION

As many as eight cultivars of sugarcane are grown commercially in Louisiana. Preemergence herbicides are most injurious in the plant cane year of the 3-year crop cycle (4,7). Ratoon cane crops are more tolerant than plant cane to hexazinone applied postemergence (4).

Morningglories (*Ipomoea* spp.) become particularly troublesome in sugarcane following layby (last) cultivations in early June. Millhollon (5) reported a sugar yield reduction as high as 30% from morningglory competition. In addition, the dense vines produced by the morningglory plants often reduce the efficiency of mechanical harvesters. Atrazine, when applied as a directed preemergence spray under the sugarcane canopy with ground equipment provides excellent control of red morningglory (*Ipomoea coccinea* L.) and several other morningglory species (5). When wet conditions prevent the use of atrazine, an aerial application of 2,4-D may be necessary to control emerged morningglories and to facilitate mechanical sugarcane harvest.

Van Overbeek (8) stated that "it would require special conditions, which rarely exist in agriculture, to kill, or even seriously damage a cane plant with 2,4-D." However, some 2,4-D injury to sugarcane plants less than three months old has been reported (1,6). In Louisiana, the amine formulation of 2,4-D at 1.7 to 2.2 kg/ha is recommended for control of annual morningglories and other broadleaf weeds. Even though this treatment provides excellent weed control, producers have expressed concern that the use of 2,4-D on sugarcane used for planting material may affect subsequent germination and emergence. Limited information is available concerning the impact of herbicide application on sugarcane used as seed cane. A study was conducted to determine the effect of a late-season application of 2,4-D (three to seven weeks prior to harvest of seed cane) on growth and yield of the plant cane crop the following year.

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<sup>1</sup>Approved for publication by the Director of the Louisiana Agricultural Experiment Station as manuscript number 89-38-3624.



## MATERIALS AND METHODS

Sugarcane cultivars CP 70-321, CP 70-330, CP 72-356, CP 72-370, CP 74-383, CP 76-301, CP 76-331, CP 78-303, and CP 78-304 were planted in Napoleonville, Louisiana, in 1983. In 1984, all cultivars except CP 76-301, CP 78-303, and CP 78-304 were planted at the St. Gabriel Research Station, St. Gabriel, Louisiana. CP 65-357 was also included in 1984. First stubble crops of the selected cultivars used for seed cane were treated with a broadcast, over-the-top postemergence application of 2,4-D at 2.2 kg/ha three (September 17) and five (August 31) weeks prior to harvest in 1983 and five (September 27) and seven (September 7) weeks prior to harvest in 1984. Herbicide treatments were applied in a spray volume of 187 l/ha. An untreated check was included for comparison. Whole stalks randomly selected from treated and untreated plots were hand-harvested on October 5, 1983, and October 30, 1984, for planting material. Stalks were planted at 8- to 10-cm depths on raised beds spaced 1.8 m apart using conventional hand-planting techniques (two running stalks with a 10% overlap). Emerged shoots were counted in April and June the following year after planting. Millable stalk populations were also determined in the fall, after which the entire plot was hand harvested and weighed to determine net cane yield. A 15-stalk sample of harvested stalks was randomly selected from each plot and crushed in a 3-roller mill to extract juice, which was analyzed for sugar content (sucrose) and Brix using standard methods (3). Yields of sugar were calculated based on total stalk weight and the theoretically recoverable sugar content of the harvested stalks (2).

The experimental design for individual cultivars planted the year following 2,4-D treatment was a randomized complete block with four replications. Plot size was 3 rows x 6.7m. Data for each year were analyzed and means were separated using Duncan's Multiple Range Test ( $P=0.05$ ).

## RESULTS AND DISCUSSION

### 1983-1984

The population of sugarcane shoots in April following 2,4-D treatment, even though not significantly different for all nine cultivars, were numerically lower than where cane was not treated (Table 1).

Table 1. Sugarcane shoot populations in April and June following 2,4-D treatment three and five weeks prior to planting in 1983 at Napoleonville, Louisiana.

Cultivar	April			June		
	3 weeks	5 weeks	Untreated	3 weeks	5 weeks	Untreated
------(no./6.7m row)-----						
CP 70-321	6 b <sup>1</sup>	12 a	15 a	24 b	31 b	56 a
CP 70-330	14	10	15	31	29	40
CP 72-356	9 b	16 a	17 a	40 b	62 a	74 a
CP 72-370	6	6	7	28	37	43
CP 74-383	15	11	17	52 ab	40 b	69 a
CP 76-301	5	5	7	31	29	38
CP 76-331	12	10	14	40	50	64
CP 78-303	10	7	14	40	28	67
CP 78-304	23	25	27	69	72	90

<sup>1</sup> Cultivar populations in each row for April and June followed by the same letter or without letters are not significantly different using Duncan's Multiple Range Test.

Only CP 70-321 and CP 72-356 cultivars showed significant stand reductions when 2,4-D was applied three weeks prior to planting but not five weeks. Based on shoot populations in April for CP 70-321 and CP 72-356, and in June for CP 72-356, application of 2,4-D three weeks prior to planting was more detrimental than

five weeks prior to planting treatment. Sugarcane populations for both CP 70-321 and CP 72-356 in April when 2,4-D was applied five weeks prior to planting and for the untreated control were similar. In June, in addition to CP 70-321 and CP 72-356, shoot populations for CP 74-383 were also significantly reduced. For both CP 70-321 and CP 74-383, reductions in shoot populations were similar regardless of time of 2,4-D application. For CP 70-321 both applications of 2,4-D significantly reduced sugarcane shoot populations. Only application five weeks prior to planting reduced shoot populations of CP 74-383.

In general for all cultivars in 1984, application of 2,4-D reduced stalk populations at harvest, and cane and sugar yields. Significant reductions, however, were noted only for CP 70-321 and CP 74-383 (Table 2).

Table 2. CP 70-321 and CP 74-383 stalk populations at harvest, and cane and sugar yields as influenced by 2,4-D treatment three and five weeks prior to planting in 1983 at Napoleonville, Louisiana.

Treatment time	CP 70-321			CP 74-383		
	Stalk population	Yield		Stalk population	Yield	
		Cane	Sugar		Cane	Sugar
	(no./ha)	(mt/ha)	(kg/ha)	(no./ha)	(mt/ha)	(kg/ha)
3 weeks	26449 b <sup>1</sup>	36.6 ab	2955 b	55363 b	61.6 b	5082 b
5 weeks	33844 b	34.8 b	3645 b	41913 c	46.3 c	4145 b
Untreated	54690 a	37.4 a	6430 a	73070 a	80.2 a	6981 a

<sup>1</sup> Numbers in each column followed by the same letter are not significantly different using Duncan's Multiple Range Test.

For CP 70-321, millable stalk populations were equivalent when 2,4-D was applied three and five weeks prior to planting and averaged 45% lower than the untreated check. Sugar yield of CP 70-321 following 2,4-D treatment to seed cane was reduced 49%. For CP 74-383, application of 2,4-D significantly reduced millable stalk populations and yields of cane and sugar. Millable stalk populations and cane yields were lower when 2,4-D was applied at five weeks prior to planting compared with three weeks. Sugar yields were similar regardless of time of 2,4-D application. Compared with the untreated check, application of 2,4-D reduced CP 74-383 stalk population, cane yield, and sugar yield an average of 33, 33, and 34%, respectively.

#### 1984-1985

Sugarcane populations in April and June for the seven cultivars were generally reduced when 2,4-D was applied either five or seven weeks prior to planting (Table 3). Significant differences in populations in April, however, occurred for only CP 74-383. In June, sugarcane populations were significantly lower when 2,4-D was applied five weeks prior to planting for CP 70-330, CP 72-356, CP 74-383, and CP 76-331. For CP 70-330 and CP 72-356, shoot populations were comparable with the untreated check when 2,4-D was applied seven weeks prior to planting. June shoot populations were significantly lower than the untreated check when 2,4-D was applied seven weeks prior to planting for CP 74-383 and CP 76-331. In the case of CP 76-331, June shoot populations following the 2,4-D treatment seven weeks prior to planting were significantly lower than the five weeks prior to planting treatment. Significant differences in millable stalk populations at harvest, and cane and sugar yields, unlike the previous year, were not noted in 1985 (Table 4).

Table 3. Sugarcane shoot populations in April and June following 2,4-D treatment five and seven weeks prior to planting in 1984 at St. Gabriel, Louisiana.

Cultivar	April			June		
	5 weeks	7 weeks	Untreated	5 weeks	7 weeks	Untreated
------(no/6.7m row)-----						
CP 65-357	14	13	10	31	44	32
CP 70-321	22	24	27	55	66	64
CP 70-330	28	30	32	45 b <sup>1</sup>	63 a	61 a
CP 72-356	30	25	32	62 b	72 a	78 a
CP 72-370	23	21	22	60	47	51
CP 74-383	17 b	18 b	23 a	56 b	58 b	72 a
CP 76-331	25	21	30	69 b	49 c	83 a

<sup>1</sup> Cultivar populations in each row for April and June followed by the same letter or without letters are not significantly different using Duncan's Multiple Range Test.

Table 4. Stalk populations at harvest, and cane and sugar yields averaged across cultivars as influenced by 2,4-D treatment three and five weeks prior to planting in 1983 at Napoleonville, Louisiana, and five and seven weeks prior to planting in 1984 at St. Gabriel, Louisiana.<sup>1</sup>

Treatment time	1983-1984			1984-1985		
	Stalk population	Yield		Stalk population	Yield	
		Cane	Sugar		Cane	Sugar
	(no/ha)	(mt/ha)	(kg/ha)	(no/ha)	(mt/ha)	(kg/ha)
3 or 4 weeks	43035 b <sup>2</sup>	55.7 b	5022 b	59393	71.7	8019
5 or 7 weeks	43551 b	56.3 b	5092 b	58726	72.6	5869
Untreated	56034 a	71.2 a	6631 a	59711	73.5	8518

<sup>1</sup> Averaged across nine cultivars in 1983-1984 and seven cultivars in 1984-1985.

<sup>2</sup> Numbers in each column followed by the same letter or without letters are not significantly different using Duncan's Multiple Range Test.

In summary, reductions in early-season sugarcane populations occurred both years, but cane and sugar yields were reduced only in 1984 for CP 70-321 and CP 74-383. Even though early differences in sugarcane stands were detected in 1985, sugarcane apparently compensated by increased tillering and late-season populations were unaffected. Late-season applications of 2,4-D in September when cane is approaching maturation are atypical and observed responses may not occur when applications are made in June or July when sugarcane is actively growing vegetatively. This response is not unique to sugarcane since other grass crops such as rice (*Oryza sativa* L.) tolerates 2,4-D early in the vegetative stage but is injured when applied during the reproductive stage. Since the potential exists for reduced stands when seed cane is treated with 2,4-D, late-season "rescue-type" applications of 2,4-D should be avoided in fields intended for use as seed cane nurseries. Use of atrazine or another alternative preemergence herbicide for broadleaf weed control at layby should be considered.



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## SUGARCANE RESPONSE TO SELECTED PREEMERGENCE AND POSTEMERGENCE HERBICIDES<sup>1</sup>

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### ABSTRACT

Field studies were conducted over three years in an area largely free of competitive weeds to determine the influence of herbicides with pre- and/or postemergence activity on CP 65-357 sugarcane (*Saccharum interspecific hybrid*). Herbicides with known activity on grass and broadleaf weeds prevalent in sugarcane were applied to first stubble crops in March 1983 and April 1984, and to a plant crop in May 1986 at the 3- to 6-leaf growth stage. Visual sugarcane injury, manifested as chlorosis, necrosis, and/or reduction in height, was excessive for imazaquin (2 yr), imazapyr (2 yr), imazethapyr (1 yr), and clethodim (1 yr). Reductions in stalk populations at harvest and sugar yields compared to standard herbicides and an untreated check generally accompanied the significant (>15%) early season injury from these herbicides. Visual injury also was observed in 1986 for metribuzin + chlorimuron at 0.48 + 0.08 kg/ha and clomazone at 1.1 kg/ha, but yields were unaffected. Sugarcane appeared to be tolerant to fomesafen at 0.56 kg/ha (2 yr), BAS-514 at 0.17 kg/ha (1 yr), norflurazon at 1.1 kg/ha (2 yr), chlorimuron at 0.009 kg/ha (1 yr), triclopyr + 2,4-D at 1.1 + 2.2 kg/ha (1 yr), and hexazinone at 0.50 kg/ha (1 yr), producing cane and sugar yields comparable to that observed with the untreated check and standard treatments of either metribuzin (2.2 kg/ha), terbacil (1.1 kg/ha), trifluralin (2.2 kg/ha), or asulam (3.4 kg/ha).

### INTRODUCTION

In Louisiana, as many as eight cultivars of sugarcane are grown commercially. Differences in tolerance of sugarcane cultivars to metribuzin (6), hexazinone (4,6), terbacil (2,6), fenac, and dalapon (2,5) have been reported. Sugarcane generally can tolerate preemergence and postemergence herbicide treatments phytotoxic to most grass crops since root and shoot buds on sugarcane seed pieces (following planting) and on stubble are located in the soil well below the herbicide zone. In addition, the coarse, nonsucculent leaves hinder the absorption of postemergence herbicides and may account for sugarcane tolerance to these treatments (5).

New herbicides being evaluated in other crops for the control of johnsongrass (*Sorghum halepense* (L.) Pers.), itchgrass (*Rottboellia cochinchinensis* (Lour.) Clayton), and other weeds may also hold promise for the control of these troublesome weeds in sugarcane. However, since registration costs are high and returns on investment limited, evaluations of these herbicides for use in sugarcane are generally delayed. In the hope of stimulating manufacturer interest in the registration of herbicides for sugarcane, studies were conducted to evaluate the response of sugarcane to injury from non-registered herbicides with pre- and/or postemergence activity against weeds considered troublesome in sugarcane.

### MATERIALS AND METHODS

Field studies were conducted during 1983, 1984, and 1986 at the St. Gabriel Research Station near St. Gabriel, Louisiana, on a silt loam soil with a pH of 6.0 and an organic matter content of 0.83%. Herbicides were applied as broadcast postemergence sprays over-the-top of sugarcane on March 29, 1983; April 30, 1984; and May 22, 1986. First stubble crops of the cultivar CP 65-357 first stubble cane were used in 1983 and 1984, and

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a plant cane crop was used in 1986. Each year herbicides were applied to sugarcane in the 3- to 6-leaf stage of development in a spray volume of 215 L/ha (1983), 200 L/ha (1984), and 187 L/ha (1986).

Visual injury ratings based on chlorosis, necrosis, and/or reductions in shoot height were made on June 7 (1983 and 1984) and June 10 (1986) which corresponded to 70 (1983), 38 (1984), and 20 (1986) days after treatment (DAT). Ratings were based on a scale of 0 = no injury and 100% = complete kill. Stalk population was determined by counting millable stalks (stalks having a visible dewlap in the collar region of the leaf at least 1.2 m above the soil surface) just prior to harvest. Stalk height was measured from ground level to the tip of the longest leaf. Plots were harvested by hand and weighed to determine net cane yield (tonnage). Fifteen harvested stalks were randomly selected from each plot and crushed in a three-roller mill to extract juice which was analyzed for sugar content (sucrose) and Brix using standard methods (3). Yields of sugar were calculated based on total stalk weight and the theoretically recoverable sugar content of the harvested stalks (1).

The experimental design consisted of a randomized complete block with four replications per treatment. Experimental plots were three rows (1.8 m wide) by 9.1 m long. Data were subjected to analysis of variance, and differences among means were determined using Fisher's Least Significant Difference Test ( $P = 0.05$ ).

## RESULTS AND DISCUSSION

### 1983

Sugarcane response to imazaquin and fomesafen was compared to standard herbicide treatments of terbacil, metribuzin, and hexazinone. Significant sugarcane injury (>70%), manifested as slight chlorosis and necrosis and significant stunting, was observed 70 DAT in plots treated with imazaquin at rates of 0.14 to 0.56 kg/ha (Table 1).

Table 1. Visual injury, millable stalk height and population, sucrose content of crushed juice, and cane and sugar yield of first stubble CP 65-357 as influenced by postemergence herbicide treatments at St. Gabriel, Louisiana, 1983.

Herbicide	Rate of application (kg/ha)	Injury 70 DAT (%)	Stalk		Sucrose (%)	Yield	
			Height (m)	Population (no./ha)		Cane (mt/ha)	Sugar (kg/ha)
Untreated check	----	0	4.3	51272	16.8	44.4	4195
Terbacil	1.10	1	4.2	72042	16.0	57.8	5080
Metribuzin	2.20	1	4.0	66616	16.7	54.9	5178
Imazaquin	0.14	72	3.6	46594	14.4	31.6	2564
	0.28	74	3.4	51458	14.8	38.1	3149
	0.56	79	3.2	43225	14.7	19.7	1572
Fomesafen	0.56	5	4.3	65304	15.8	51.1	4499
	0.84	5	4.0	67550	16.2	55.1	5057
Hexazinone	0.50	8	3.9	66053	16.0	57.3	5132
R-40244	2.20	5	4.3	49588	15.9	40.8	3689
	4.50	8	4.3	64744	16.2	52.6	4789
LSD(0.05)		12	0.6	16025	1.4	15.7	1559

Injury with fomesafen and R-40244 was minimal. Millable stalk heights were reduced at all imazaquin rates evaluated when compared to the untreated check. Stalk populations for the imazaquin treatments, even though similar to the untreated check, were lower than standard treatments of either terbacil or metribuzin. Early season weed competition may account for the reduced stalk populations in the untreated check. Additionally, cane per hectare, sugar per hectare, and sucrose content following imazaquin treatment were lower

than the standard treatments. Sugarcane injury following treatment with fomesafen and R-40244 was minimal (<10%) and comparable to the standard treatments. Sugar yields following the application of fomesafen and R-40244 were comparable to the untreated check and the standard treatments indicating some tolerance to these herbicides.

#### 1984

Evaluations with R-40244 and imazaquin were continued in 1984 and expanded to include imazapyr and nonflurazon. Visual sugarcane injury 38 DAT with R-40244 was minimal and was similar to that observed the previous year (Table 2). Stalk height and population, and yield components following treatment with R-40244 were also comparable to the standard herbicide treatments indicating that sugarcane was tolerant to this herbicide.

Table 2. Visual injury, millable stalk height and population, and cane and sugar yield of first stubble CP 65-357 as influenced by postemergence herbicide treatments at St. Gabriel, Louisiana, 1984.

Herbicide	Rate of application	Injury 15 DAT	Stalk		Sucrose	Yield	
			Height	Population		Cane	Sugar
	(kg/ha)	(%)	(m)	(no./ha)	(%)	(mt/ha)	(kg/ha)
Untreated check	-	3	5.0	46172	16.7	39.9	3821
Terbacil	1.10	0	5.0	60965	16.0	56.7	5107
Metribuzin	2.20	0	4.3	49533	16.0	44.8	4316
Imazaquin	0.28	4	4.1	39448	14.9	34.5	2862
	0.56	5	3.8	60517	15.5	46.1	4100
	0.84	4	4.1	56034	16.1	40.5	3540
R-40244	2.20	4	3.5	48414	15.8	44.8	4299
	4.50	1	4.0	66793	15.6	57.3	5096
Imazapyr	0.04	1	4.6	47518	15.9	37.9	3415
	0.08	10	4.0	48190	14.5	37.2	3157
	0.14	19	3.2	41242	15.7	32.5	2899
	0.28	35	1.8	19424	15.6	15.9	1412
	0.54	23	1.1	28689	15.6	18.4	1670
Nonflurazon	0.56	0	4.8	43931	15.0	39.9	3292
	1.10	0	4.8	29586	15.7	24.9	2266
	1.70	0	4.3	51104	15.9	42.8	3847
LSD (0.05)	-	9	0.8	NS	NS	NS	NS

Unlike the previous year, sugarcane injury with imazaquin, which provides both annual grass and broadleaf weed control in soybeans, was slight ( $\leq 5\%$ ). As in 1983, millable stalk heights when compared to the untreated check were reduced by approximately 20% by all rates of imazaquin evaluated (Table 2). Reductions in stalk height did not significantly affect yield, however. The higher injury for imazaquin in 1983 as compared to 1984 may have been due to greater root and shoot uptake of imazaquin associated with the earlier application. Visual sugarcane injury was significantly higher ( $\geq 19\%$ ) following treatment with imazapyr, which is a nonselective herbicide used on ditchbanks and rights-of-ways, at rates of 0.14 kg/ha and higher. Compared to the terbacil and metribuzin standards, stalk heights were significantly decreased only when the rate of imazapyr exceeded 0.14 kg/ha. Cane and sugar yields were generally depressed when imazapyr rates exceeded 0.14 kg/ha indicating questionable selectivity potential in sugarcane.



Norflurazon is currently labeled for control of broadleaf weeds and annual grasses in cotton (*Gossypium hirsutum* L.). No visual sugarcane injury was observed 15 DAT with norflurazon (Table 2). With the exception of the 1.1 kg/ha rate of norflurazon, sugarcane growth and yield were generally unaffected.

### 1986

Evaluations were expanded in 1986 to include several new herbicides as well as those evaluated in previous years. Visual sugarcane injury ranged from chlorosis and stunting to almost complete kill. Significant injury ( $\leq 15\%$ ) 20 DAT was noted for metribuzin + chlorimuron, imazaquin, imazapyr, imazethapyr, SC-0774, clethodim, and clomazone (Table 3).

Table 3. Visual injury, millable stalk height and population, and cane and sugar yield of plant cane CP 65-357 as influenced by postemergence herbicide treatments at St. Gabriel, Louisiana 1986.

Herbicide	Rate of application	Injury 20 DAT	Stalk Population	Yield	
				Cane	Sugar
	(kg/ha)	(%)	(no./ha)	(mt/ha)	(kg/ha)
Untreated check	-	0	80920	103.0	9551
Fomesafen	0.56	10	90333	107.5	9961
Lactofen	0.22	3	84057	103.0	9208
Metribuzin + Chlorimuron	0.48 + 0.08	20	89886	89.6	7579
	0.96 + 0.16	15	91454	91.8	7986
Chlorimuron	0.009	0	89661	123.2	10968
Linuron + Chlorimuron	1.03 + 0.09	8	82488	100.8	8869
BAS-514	0.17	5	84281	105.3	9424
Imazaquin	0.21	30	79126	89.6	7380
Imazapyr	0.11	43	64331	67.2	5891
Imazethapyr	0.14	33	72625	76.2	6831
Triclopyr + 2, 4-D	1.1 + 2.2	8	89436	100.8	8956
Cinmethayin	0.84	10	84506	87.4	7599
SC-0774	1.10	23	89436	94.1	7377
SC-0051	1.10	0	83610	85.1	6877
Norflurazon	1.10	3	83610	107.5	8762
Clethodim	0.28	68	16295	24.6	1630
Clomazone	1.10	20	84281	100.8	8975
Asulam	3.40	3	85403	114.2	9754
LSU (0.05)		12	15566	13.4	2053

Imazapyr at 0.11 kg/ha and clethodim at 0.28 kg/ha caused 43 and 68% injury, respectively. Stalk populations were reduced 21 and 80% compared to the untreated check where imazapyr and clethodim were applied, respectively. Injury to sugarcane with clethodim would be expected since it is a postemergence grass herbicide. Cane and sugar yields were reduced significantly when these herbicides were applied. Significant reductions in cane and sugar yields also were noted with imazethapyr and SC-0051. Cane yields were reduced with cinmethylin, and sugar yields were significantly reduced with SC-0774 indicating some susceptibility. Neither cinmethylin nor SC-0774 reduced sugarcane stalk populations. Sugarcane was extremely tolerant to fomesafen at 0.56 kg/ha, lactofen at 0.22 kg/ha, chlorimuron at 0.009 kg/ha, linuron + chlorimuron at 1.03 + 0.09 kg/ha, BAS-514 at 0.17 kg/ha, triclopyr + 2, 4-D at 1.1 + 2.2 kg/ha, and the asulam standard.



## CONCLUSIONS

In conclusion, several herbicides registered for use or being evaluated for use in other crops may have promise for weed control in sugarcane. Even though some phytotoxicity was observed shortly after treatment, injury was short-lived and sugarcane yields were not affected. In addition, some of the herbicides evaluated, even though injurious to sugarcane, may offer advantages in non-cropland, ditchbank, and/or fallow programs. Studies of this nature are important in speeding up the process of identifying potential new herbicides for controlling weeds in crops such as sugarcane which are grown on a limited acreage. In addition, these studies delineate the negative response of sugarcane to herbicides which is important in assessing the impact from misapplication.

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## LOSSES CAUSED BY RATOON STUNTING DISEASE OF SUGARCANE IN FLORIDA

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### ABSTRACT

Ratoon stunting disease yield-loss trials were harvested at four locations in plant cane and first ratoon and at three locations in second ratoon. Four clones in both the RSD-infected and RSD-free state were examined at two locations each on muck soils and sand soils. Losses in sugar per hectare caused by RSD averaged 5% across all clones and harvests. Losses in CP 65-357, CP 70-1133, and CP 72-1210 were similar and statistically significant; loss in CP 74-2005 was not statistically significant. Losses were greater on sand than on muck ( $P < 0.07$ ). The absolute loss to the Florida sugar industry was estimated at \$27.2 million for the 74% of the hectareage occupied by the four clones in 1988-89. This calculation was based on the percentage loss detected in the trials for each clone and soil type, the percentage of the total Florida hectareage occupied by each clone, and the percentage of each clone's hectareage grown on sand and muck. If this loss is projected linearly to the total hectareage of Florida, the estimated loss in raw sugar value for the 1988-89 crop is \$36.8 million or \$206 per hectare (\$92 per acre). The cost of adding RSD to the joint breeding program of the USDA, the University of Florida, and the Florida Sugar Cane League is estimated at about 0.3% of the annual loss of raw sugar caused by RSD.

### INTRODUCTION

Ratoon stunting disease of sugarcane (RSD) caused by the xylem inhabiting coryneform bacterium, *Clavibacter xyli* subsp. *xyli* Davis et al (10), is widely regarded as causing greater economic loss to the cane sugar industries of the world than any other disease (15); yet paradoxically no other disease of sugarcane is less conspicuous. Because sugarcane infected with the RSD bacterium is overtly symptomless, the disease is often unnoticed even when losses are significant. This is especially true in Florida where drought stress, which enhances the effects of RSD (19), is rare in sugarcane.

RSD incidence surveys in Florida (7, 16; Davis and Dean, unpublished) suggest that clones emerging from the USDA-IFAS-Florida Sugar Cane League breeding program at Canal Point, Florida, go through the normal eight years of agronomic testing essentially free of RSD, then gradually become 100% infected over the next five or six years after their release to the industry. At least this appears to be true of clones having about the same degree of RSD resistance as the most widely grown clones such as CP 72-1210 and CP 70-1133.

RSD yield-loss, as estimated in this report and in a previous report by Irely (17), when considered together with data on the incidence of RSD in Florida commercial cane, indicates that although losses are relatively small on a percentage basis, they are large in absolute value because the percentage applies to a large base (essentially the entire hectareage in Florida every year). Even on a percentage basis, the losses are large in relation to any reasonable estimate of the cost of controlling RSD.

The primary goal of our research on RSD is to control the disease by breeding for resistance. Roach (18) has made the case that control of RSD through heat treatment has been generally less than satisfactory around the world, and that breeding for resistance would be a feasible alternative if the technology for screening adequate populations becomes available. The yield-loss trails reported here were necessary for assessment of the economic need to control RSD under the unique conditions that prevail in Florida. Data bearing on the issue were published by Irely (17). Our estimates of yield losses are very close to his on those clones tested in common on the same soil type.

## MATERIALS AND METHODS

Four RSD yield-loss trials, two on sand and two on muck soils, were installed in the winter of 1985. One of the muck-land trials was with the New Hope Sugar Cooperative near Twenty-Mile Bend and the other was with Okeelanta near the Okeelanta Mill. The sand locations were both in Glades county near Moorehaven. One was with Lykes Brothers and the other with A. Duda and Sons. The four clones tested at all locations were CP 65-357, CP 70-1133, CP 72-1210, and CP 74-2005. Each clone appeared in both the healthy (RSD free) and infected state in each of eight replications at each location. The experimental design was a split plot arranged in randomized complete blocks with clones as main plots and infection states as subplots. Each subplot was surrounded on four sides by 4.6 m of clear space to minimize spread of RSD into healthy plots. Subplots were four rows 5.3 m long, and rows were spaced 1.5 m apart. The planting rate for seedcane was two lines of cane. Other cultural practices were determined by the grower-cooperator and were applied at the same time and in the same manner as to his surrounding commercial fields.

The seed source for all trials was the plant crop from a seed increase nursery at Canal Point. The nursery had been established from healthy and infected plants obtained a generation earlier by hot water treatment (51° C for two hr) of all seedcane followed by re-inoculation of half of the seedcane with the F<sub>1</sub> strain (11) of *C. x. subsp. xyli*. The infection status of seedcane taken from the increase nursery was confirmed by examining samples of extracted xylem sap from stalks for the presence of *C. x. subsp. xyli* by light microscopy.

At the time of harvest, all cane was cut and piled by hand, then weighed with a tractor mounted weighing device. Ten whole stalks were selected randomly from each plot, bundled, and transported to the USDA laboratory at Canal Point where they were weighed, milled, and the crusher juice analyzed. Values for kg of sugar per tonne of cane (ST) were calculated according to Arceneaux's simplification of the Winter-Carp-Geerligs formula (2). Since the effect of RSD on the varietal correction factor (VCF) is unknown, a VCF of one was used for all clones and infection states.

Plant cane and first ratoon crops were harvested from all trials. A second ratoon was harvested from three trials. The trial at Duda was not harvested in second ratoon because of scheduling problems.

Variance was analyzed for data from each location for each year separately, for four locations and two years combined, for three locations and three years combined, and for all locations and years combined for the trials that were harvested. When a multiple comparison procedure was appropriate, Fisher's unprotected, 1-tailed, LSD was used for tonnes of cane per hectare (TCH) and tonnes of sugar per hectare (TSH), because these parameters are either affected adversely or are not significantly affected by RSD. The 2-tailed version of the same procedure was used for kg of sugar per tonne of cane (ST), because it may be either increased or decreased by RSD depending on the state of maturity of the cane at harvest (3, 17).

## RESULTS

Table 1 shows the mean values for the principal yield components, TCH, ST, and TSH, broken down by location, year, clone, and infection state. A trend toward loss caused by RSD is discernable in Table 1 but not obvious. Fisher's LSD indicated clone comparisons of healthy and infected cane at individual locations and years (eight replications). If the apparent RSD losses had been due simply to sampling error, only 2.2 of those comparisons would be expected to test as significant. Given the relative magnitudes of random variance and real loss in these trials, it is apparent that eight replications are not enough for consistent statistical detection of loss. In the analysis of individual locations and years, significance for infection state as a mean of all clones was reached in only two of the eleven trials and closely approached in two others.

However, a consistent picture emerged when years and locations were combined in one analysis. Loss in sugar per Ha caused by RSD averaged 5% across all clones, locations and years ( $p = 0.0001$ ) (Figure 1). Although clones interacted significantly with both locations and years ( $p = 0.0001$ ), infection state interacted significantly with neither. Whether the combined analysis involved four locations and two years, three locations and three years, or all harvests, made no difference in conclusions about RSD losses except with respect to CP 74-2005. The loss in this clone was significant in plant cane and first ratoon at the 5% level, but not in the



analysis of all harvests in which the sand location showing the greatest loss in CP 74-2005 was missing. This indication of slightly greater resistance to RSD in CP 74-2005 is consistent with previous data on the size of pathogen populations and the number of infected vascular bundles found in this clone (9, 14).

Table 1. Effect of ratoon stunting disease on yields of four clones of sugarcane at four locations in Florida in three crops.<sup>1</sup>

Clone	Infection state	Duda			Lykes			Okeelanta			New Hope		
		ST	TCH	TSH	ST	TCH	TSH	ST	TCH	TSH	ST	TCH	TSH
Plant Cane Crop (1986-1987)													
CP 65-357	H	124.9	166.2	21.04*	108.6	100.6	10.90	96.0	169.8	16.41*	97.7	102.5	9.99
	D	120.9	158.5	19.39	105.3	89.4	9.56	95.2	162.7	15.61	101.2	102.8	10.46
CP 70-1133	H	122.9	170.4	21.20*	112.9	109.8	12.36	90.4	191.0	17.42	95.2	151.4	14.42
	D	125.9	153.0	19.47	105.5	110.1	11.58	92.5	194.0	18.08	103.0	133.3	13.63
CP 72-1210	H	128.4	176.3	22.86*	100.2	93.5	9.43	102.5	198.1	20.46	111.0	136.4	15.16*
	D	127.1	163.7	21.07	99.5	109.0	10.93	102.3	198.8	20.45	98.5	132.0	12.98
CP 74-2005	H	135.8	171.0	23.48*	106.8	99.4	10.56	109.6	206.3	22.77*	112.0	123.7	13.82
	D	131.4	163.6	21.76	102.2	92.0	9.46	108.0	194.3	21.14	109.3	132.4	14.46
First Ratoon Crop (1987-1988)													
CP 65-357	H	120.2	109.9	12.95	128.9	87.1	11.18	114.5	148.0	16.95*	109.5	103.2	11.36
	D	110.8	115.8	12.78	130.1	81.3	10.52	115.5	138.5	16.00	111.7	107.8	12.07
CP 70-1133	H	114.5	128.7	14.59	134.8	82.8	11.17*	118.5	160.2	18.98	114.6	149.9	17.19
	D	118.7	118.1	13.97	134.3	72.3	9.71	118.6	155.6	18.44	115.1	144.3	16.62
CP 72-1210	H	123.6	110.5	13.70*	129.9	58.1	7.52	122.6	134.9	16.52*	116.5	111.3	12.91
	D	123.9	92.9	11.48	132.4	59.0	7.94	121.1	128.9	15.61	116.1	110.6	12.82
CP 74-2005	H	120.8	95.7	11.55	142.5	62.6	8.86*	120.5	156.9	18.92	117.2	120.6	14.15
	D	120.0	102.0	12.28	138.5	43.8	6.06	124.1	154.7	19.20	112.4	126.5	14.28
Second Ratoon Crop (1988-1989)													
CP 65-357	H				130.0	69.0	8.91*	125.9	120.6	15.15	128.3	101.3	12.99
	D				133.2	39.4	5.25	129.2	119.5	15.44	127.9	96.3	12.28
CP 70-1133	H				134.9	91.6	12.37*	128.2	109.6	14.05	134.5	133.1	17.94*
	D				132.8	73.2	9.85	125.4	110.9	13.90	134.4	122.0	16.39
CP 72-1210	H				133.5	65.1	8.72	127.2	105.2	13.41	134.7	106.8	14.39*
	D				131.3	51.9	6.89	131.1	101.8	13.36	131.3	95.6	12.56
CP 74-2005	H				139.9	40.3	5.56	128.4	118.7	15.26	131.8	105.0	13.84
	D				139.3	51.0	7.09	126.7	119.9	15.22	132.7	104.7	13.87

<sup>1</sup> The Duda and Lykes locations were on sandy soils; the Okeelanta and New Hope locations were on muck soils. Each value is the mean from eight replications. Abbreviations: ST = kilograms of sugar/tonne of cane; TCH = tonnes of cane/hectare; TSH = tonnes of sugar/hectare; H = healthy; D = diseased. Asterisk (\*) indicates significant difference ( $p < 0.05$ ) between infection states.

Since only one sand location was harvested in second ratoon, only the plant cane and the first ratoon crops were combined in the analysis comparing RSD losses on sand and muck. Figure 2 shows that losses caused by RSD were greater on sand than on muck in three of the four clones at the end of the first ratoon when the data set was still balanced for soil type. The losses were 2.75 times as great on sand as a mean of all clones. This difference did not quite make the 5% level of significance ( $p = 0.069$ ), because of the reversal in CP 72-1210 in which losses were significantly greater on muck ( $p < 0.05$ ).



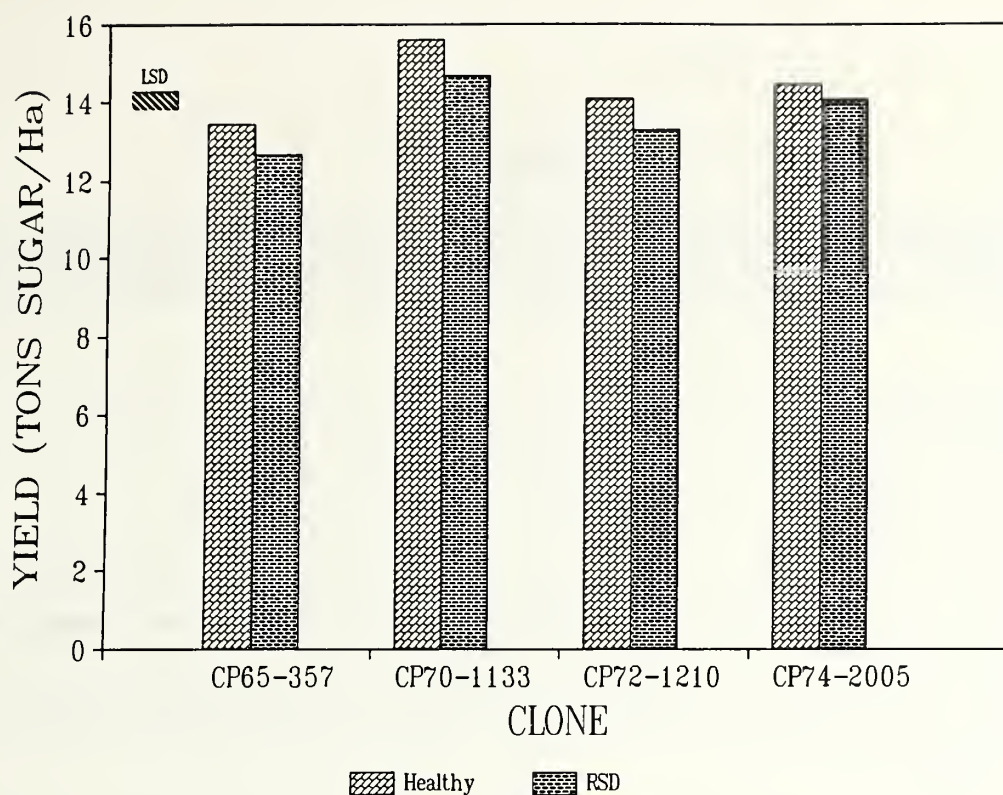


Figure 1. Effect of ratoon stunting disease on yield of four sugarcane clones.

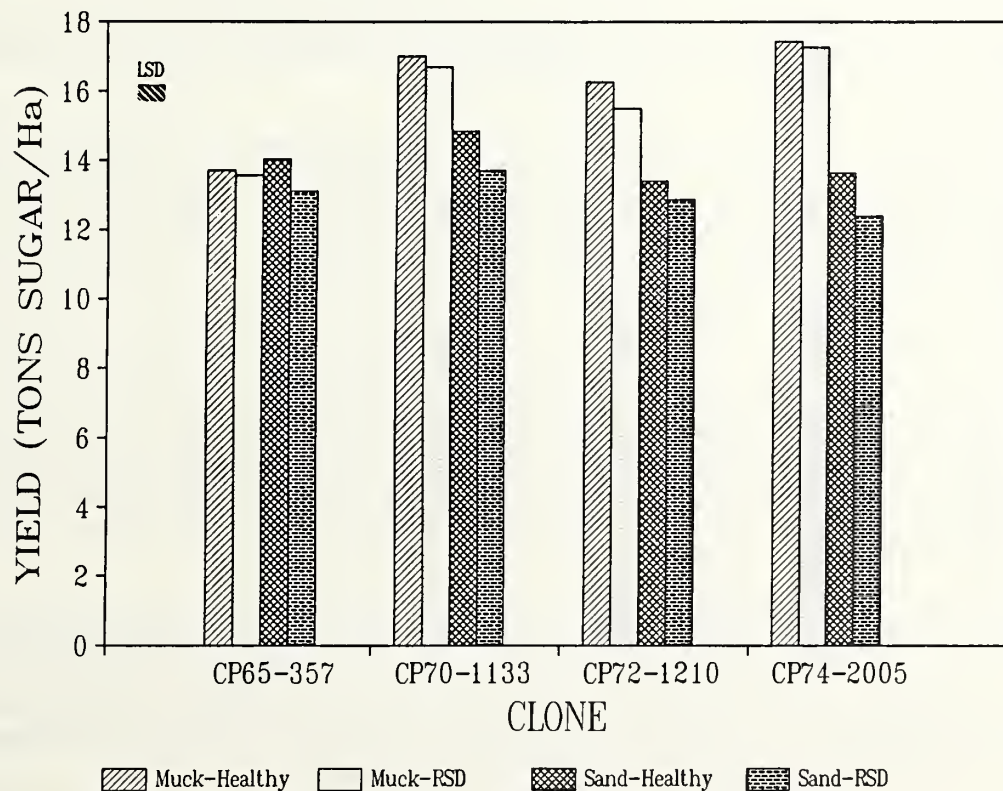


Figure 2. Effect of ratoon stunting disease on yield of four sugarcane clones on two soil types. Data represent the means for plant and first ratoon crops.

## DISCUSSION

There was no evidence that yield loss caused by RSD increased with year in the crop cycle. The loss was greatest in plant cane and second ratoon, and smallest in first ratoon. The loss was only slightly greater in the second ratoon than in the plant crop and may have related more to the drier growing season than to year in the crop cycle.

Irey (17) reported RSD-induced enhancement of percent sucrose in early harvested cane in Florida, an effect which diminished with advancing cane maturity. We saw no such effect in our trials, probably because all trials were at least 12 months old at harvest. Our data suggest that there may even have been a loss in sucrose due to RSD ( $p = 0.14$ ). Baily and Bechet (3) reported a small, RSD-induced, statistically non-significant loss in sugar per unit of stalk weight as a mean of eight clones in a three-year crop cycle.

Estimates of the percent loss in TSH for each of the four clones tested on each soil type are available from results of these trials. The percent of the commercial hectareage in Florida occupied by each of these clones was estimated by Coale and Glaz (4) from a large sample. If the appropriate loss percentages are applied to the appropriate hectareage of each of the four clones tested, the loss on the 74% of the hectareage occupied by these four clones is calculated as \$27.4 million for raw sugar only. This calculation is based on 1988-89 production figures and 1987-88 sugar prices (the latest available). A further unavoidable assumption is that the four clones in the trial produced a proportion of the total 1988-89 raw sugar that would be indicated by their share of the hectareage.

If it is assumed that losses in the four clones comprising 74% of the hectareage in Florida are close to the average for the remaining 26% of the hectareage, then the total loss to the Florida sugar industry in raw sugar only in 1988-89 is estimated at \$36.8 million or an average of \$206 per hectare (\$92 per acre). There are foreseeable changes, both genetic and environmental, that could increase RSD losses in Florida. The shift of sugarcane production from muck soils to sand soils, a process that is already well underway, is expected to accelerate as the organic soils subside (1). This will lead to substantial increases in RSD-induced yield loss if the average level of clonal resistance to RSD does not change.

Apparently RSD losses are now lower than they were in the past. Losses reported by Todd (20) were considerably above current estimates. Losses in CL 41-223, which once occupied as much as 90% of Florida hectareage, were in the 15 to 16% range (12, 20). Since Florida clones are released before the incidence of RSD becomes significant in them, the current lower level of loss (higher resistance of clones) must be regarded as having come about by chance. There is a clear danger that without selection pressure in the breeding programs, current resistance levels may not be maintained.

Until recently, breeding for resistance to RSD has not been seriously considered, mainly because an adequate screening procedure was not available, and probably partly because heat therapy of seedcane was regarded as an effective control measure. In principle, there is no doubt that RSD can be controlled by heat therapy. In practice, it generally has not worked as well as expected (18). The reason seems to be that for success the method requires careful control of the treating process, inspection of the result, and great care to prevent or at least retard reinfection. In short, a very high level of dedication to the effort is necessary for almost everyone directly involved in cane production. That level of dedication appears to be difficult to sustain over the long run, particularly when the cane looks healthy, even if diseased.

Recent research has shown that several parameters correlate well with yield loss due to RSD (6, 8, 9, 12, 13, 14). It appears likely that one or more of these parameters can be utilized in a breeding program to rank clones for RSD resistance without the prohibitive cost of yield trials on large numbers of clones. An adequate screening procedure appears to be attainable. RSD-induced yield losses in Florida are high enough to assure that the cost of adding RSD to the breeding program could be financed by 0.3% (or less) of the annual loss. Control of RSD through breeding would be sustainable over the long run.



## ACKNOWLEDGEMENTS

The RSD yield-loss trials reported here are part of a cooperative project between the USDA at Canal Point and the University of Florida at Fort Lauderdale. The project is funded in part by the Florida Sugar Cane League, and substantially aided by commercial sugarcane growers through contributions of land, plot care, and harvest costs. The technical assistance of Cynthia Warmuth is gratefully acknowledged.

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**STUDY OF THE DEVELOPMENT OF SUGARCANE RUST  
*PUCCINIA MELANOCEPHALA*, UREDINI BY ARTIFICIAL  
INOCULATION OF HIGHLY SUSCEPTIBLE SUGARCANE CLONES**

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**ABSTRACT**

Three sugarcane cultivars, highly susceptible to sugarcane rust, *Puccinia melanocephala* H. Syd. and P. Syd., were inoculated artificially by dropping 0.5 ml of a uredospore suspension into the whorl of two tillers on container-grown plants. Plants were held outdoors under normal daytime conditions after infection and held in temperature and light-controlled shelters at either 20°C or 30°C at night to investigate the effect of temperature on post-infection disease development. Numbers of visible flecks (assumed initial infection sites), undeveloped and sporulating uredinia were counted visually on selected leaves of inoculated plants from 5 to 21 days after inoculation on weekly intervals.

The latent period (time from inoculation to formation of sporulating uredinia) within cultivars was from 10 to more than 21 days. This range of time was wider than previously reported. There appeared to be fewer flecks observed in the lower night temperature treatment than the higher temperature treatment among cultivars, though no statistical differences were detected.

The leaf-whorl inoculation method conserved inoculum, which is difficult to collect from sugarcane, conserved space in the inoculation chamber by allowing repeated measures on the same plants, and permitted assessment of latent period and the percentage of initial infection sites that develop into mature pustules. The method did not permit assessment of the relation between the number of spores in the inoculum and the number of initial infection sites.

**INTRODUCTION**

Many artificial inoculation techniques have been employed to evaluate the relative susceptibility of cereals to foliar rusts (5,7,9,11). The most successful technique for uniform inoculation utilizes a settling tower where a measured quantity of spores is dispersed into a tall chamber (2). Spores settle on the leaves of plants arranged at the bottom of the chamber. The number of spores per unit area is determined using coated microscope slides placed in the chamber or by microscopic observation of leaf surfaces. This technique has been attempted in the sugarcane rust (*Puccinia melanocephala*)-sugarcane pathosystem with limited success (3). The size of sugarcane plants limits the use of a settling tower since a large apparatus is required to achieve proper dispersion of spores. Consequently, a large quantity of inoculum is required and only a small number of plants can be inoculated at one time.

Partial resistance to rust has been used to breed for broad-based resistance in cereal crops (8). Partial resistance to rust in the rust-cereals pathosystems has several components. The latent period length, i.e. the length of time following initial infection to development of sporulating uredinia (pustules), and the size and number of uredinia per unit of inoculum or per unit of initial infection sites are two components that can be measured to determine variation in reaction type and progress in the breeding program.

Studies of types of resistance in the rust-cereals pathosystems have indicated that responses to the disease under artificial environmental conditions may not accurately reflect responses observed in the field (Purdy, personal communication). The effects of temperature and light on initial infection and on the subsequent disease development have been investigated (12). These interactions are poorly understood and there is not general agreement on the hypotheses which have been presented (10).

Spores of *P. melanocephala* are difficult to collect from rusted sugarcane leaves and are generally short lived in storage; thus a method of determining partial resistance with very small quantities of inoculum could be useful. Partial resistance has become a subject of intense interest to Florida sugarcane breeders because of the continuing loss of promising cultivars due to breakdown of resistance, presumed to be caused by races of the rust fungus. Latent period assessment and race studies require that test plants be shielded from stray inoculum or that the inoculation site be identifiable in the presence of some stray inoculum. A leaf-whorl inoculation method offers these advantages.

The objectives of this research were to test a leaf-whorl inoculation method to see if it permitted assessment of some of the components associated with partial resistance. A further objective was to test the effect of night temperature on disease development following initial infection. The necessity for moving the plants into normal sunlight in the daytime precluded control of day temperature. The parameters estimated were (1) number of visible infection sites as evidenced by visible flecks; (2) the percentage of flecks that continue development to sporulating uredinia, and (3) the latent period. We had hoped to determine infection efficiency, but as later noted this proved impractical.

## MATERIALS AND METHODS

Seed pieces of sugarcane cultivars B 4362, CP 78-1247, and H 49-5 were planted in flats in July, 1988. Plants were transplanted to 2-gallon nursery cans in September, 1988, using a mixture of two-parts field soil (Terra Ceia muck) and one-part sand. Plants were fertilized with soluble 20-20-20 once every two weeks. Eight pots of each variety were placed randomly on each of three carts in each of two bays of the photoperiod chamber at the Sugarcane Field Station, USDA, Canal Point, Florida. The experiment was a randomized complete block design. The plants were approximately three feet tall with two to five tillers per plant at the time of the first inoculation.

Spores for inoculation were collected on March 19, 1989, from naturally-infected container-grown plants of CP 78-1247 in the greenhouse. A spore suspension containing  $3600 \pm 360$  spores/ml in distilled water was prepared immediately prior to inoculation. The germination at the time of inoculation was determined by placing a drop of the suspension on 1.5 per cent water agar incubated at  $23^{\circ}\text{C}$  in a dark chamber for four hours. The germination rate was 62 per cent.

The two tallest tillers on each plant were inoculated on March 20, 1989, by placing 0.5 ml of the spore suspension in the whorl of each tiller. The three carts in each bay were held in the dark at  $23^{\circ}\text{C}$  for 18 hours after inoculation. The carts were then pulled out of the bays each day and returned each night for 21 days. The night temperature was set at  $30^{\circ}\text{C}$  in one bay and  $20^{\circ}\text{C}$  in the other; the night length was fixed at twelve hours. Fertilization and watering were continued as before the experiment. Care was taken to keep the foliage dry during watering to prevent secondary infection.

Infection sites were counted repeatedly on one marked leaf per tiller. Flecks visible to the naked-eye have been termed initial infection sites in the context of this experiment. A leaf exhibiting approximately 50 infection sites in the infected region with sufficient separation between lesions was selected and marked for counting on each tiller. This was usually the -1 leaf (6) at the time of the first count. Plants on one cart in each bay were counted beginning 5 days after inoculation. The remaining two carts in each bay were counted the following two days. Counts were repeated on successive weeks for three weeks following inoculation.

One week after the final count from the first inoculation cycle the experiment was repeated by inoculating the same plants on April 20, 1989. The leaves inoculated during the first inoculation cycle had grown to leaf +3 or +4 thereby avoiding confusion between cycles. The spores used for inoculum were collected from field produced pustules on H 49-5. The inoculum-concentration was  $2147 \pm 215$  spores/ml with 19 per cent germination. The counting intervals were the same as in the first experiment, though only data from the second counting interval were used in the analysis due to complications in the counting procedures.



## RESULTS AND DISCUSSION

The inoculation method required that there be no water in the whorl of the plant at the time of inoculation to maintain the known spore concentration. Housing the plants in the photoperiod chambers on the night before inoculation avoided dewfall. Most varieties have from two to four leaves (leaves -1 to -4) comprising the whorl of leaves exposed to inoculum. Different cultivars will hold from 0.75 to 2.5 ml in the whorl before excess water runs out between the emerging leaves. The 0.5 ml inoculum volume was selected so that all of the inoculum would remain in the whorl and a known concentration of spores would be placed on each plant. The orientation of the emerging leaves exposes different numbers of young leaves to the inoculum. One cultivar may receive inoculum only on the oldest leaf in the whorl (leaf -1) while another may receive inoculum on two or three leaves (leaves -1, -2 and -3). Therefore, the number of infection sites arising from the number of spores applied could not be estimated by this method.

This method insures that the region of infection was distinct and leaf tissue exposed to inoculum is the same age. Tests could be repeated using the same plants thus reducing the amount of time and plant material required for conducting the experiment. The infection regions of the different inoculation cycles were distinguishable and did not confuse results of repeated tests.

Carts were exposed to the same temperature and light parameters for the first 18 hours following inoculation to supply suitable conditions for infection. Infection counts in the second inoculation cycle of the experiment were affected by an infestation of mites which interfered with accurate counting. Leaves were damaged so severely that observation beyond the second counting interval following inoculation was not possible. The first counting interval of the second inoculation yielded few clear infection sites due to extensive mite stippling. Only the second weeks' data from the second inoculation were included in the analysis.

Infection sites were visible five days after inoculation. The infection sites, small chlorotic flecks, did not appear to vary in color, size or shape on the three cultivars. Small necrotic flecks were visible in the center of the initial infection sites seven days after inoculation. Some small sporulating pustules were visible 10 days after inoculation. These general observations held true in both inoculation cycles of the experiment. The pustules observed on H 49-5 at the first counting interval in the first inoculation were observed on one tiller of one plant seven days after inoculation; these were considered anomalous.

There was no significant net change in the number of infection sites with necrotic centers between the 12-14 day and the 19-21 day observation periods. Sporulating pustules had developed from 29.4 percent of the initial infection sites on B 4362 over the same period of time, while 17.7 percent had developed on CP 78-1247 and 30.7 per cent had developed on H 49-5 (Table 1). These data indicate that many of the initial infections were developing slowly and may develop into pustules from 10 to more than 21 days after inoculation. This range is wider and longer in duration than previously reported (3). This fact indicates the latent period is highly variable under the conditions of this experiment.

Secondary infection of leaves did not occur during the course of observations in this experiment as indicated by the total number of infection sites visible at each counting interval. Though the number of sites varied, there was no significant increase in the number of sites counted from the first interval to the last.

Similar results in terms of percentage of infection sites developing necrotic centers were obtained in the second inoculation cycle. The number of initial infection sites was slightly lower, although not significantly different from numbers of infection sites in the first inoculation cycle (Table 2).

Table 1. Mean number of visible infection sites, per cent lesions with necrotic centers and per cent productive uredinia by cultivar and counting interval in first inoculation cycle.

Cultivar	Mean number of infection sites	Per cent of sites forming necrotic centers	Per cent of sites forming pustules
<u>5-7 days after inoculation</u>			
B 4362	55.6	22.4	0.0
CP 78-1247	44.0	12.9	0.0
H 49-5	47.0	17.6	1.4
<u>12-14 days after inoculation</u>			
B 4362	55.3	41.9	0.2
CP 78-1247	54.3	27.4	0.0
H 49-5	49.0	40.4	2.5
<u>19-21 days after inoculation</u>			
B 4362	50.3	37.9	29.4
CP 78-1247	41.3	38.5	17.7
H 49-5	55.7	43.1	30.7

Table 2. Mean number of visible infection sites, per cent lesions with necrotic centers and per cent productive uredinia by cultivar and inoculation cycle 12-15 days after inoculation.

Cultivar	Mean number of infection sites	Per cent of sites forming necrotic centers	Per cent of sites forming pustules
<u>First inoculation</u>			
B 4362	55.3	41.9	0.2
CP 78-1247	54.3	27.4	0.0
H 49-5	49.0	40.4	2.5
<u>Second inoculation</u>			
B 4362	34.6	33.4	2.9
CP 78-1247	48.9	33.7	0.5
H 49-5	30.6	29.5	4.1
<u>Combined inoculations</u>			
B 4362	43.3	37.0	1.7
CP 78-1247	51.4	31.0	0.3
H 49-5	38.1	34.0	3.5



Numerical differences between the two night temperature treatments in the number of initial infection sites were observed. These differences were not statistically significant (Tables 3 and 4). Sharp et al. (11) reported that the optimal temperature for post-infection development of wheat rust was higher than the optimal temperature for spore germination and penetration phases of infection. Such conditions influence epidemiology and their applicability to sugarcane warrants further detailed investigation.

Table 3. Mean number of visible infection sites, per cent lesions with necrotic centers and per cent productive uredinia by temperature treatment and counting interval in first inoculation cycle.

Temperature	Mean number of infection sites	Per cent of sites forming necrotic centers	Per cent of sites forming pustules
<u>5-7 days after inoculation</u>			
20° C	43.6	25.5	1.0
30° C	53.5	9.4	0.0
<u>12-14 days after inoculation</u>			
20° C	48.1	30.8	0.5
30° C	57.4	41.0	1.2
<u>19-21 days after inoculation</u>			
20° C	41.8	27.9	27.8
30° C	55.8	50.3	24.5

Table 4. Mean number of visible infection sites, per cent lesions with necrotic centers and per cent productive uredinia by temperature treatment and inoculation cycle at 12-15 days after inoculation.

Temperature	Mean number of infection sites	Per cent of sites forming necrotic centers	Per cent of sites forming pustules
<u>First inoculation</u>			
20° C	48.1	30.8	0.5
30° C	57.4	41.0	1.2
<u>Second inoculation</u>			
20° C	46.2	32.6	1.3
30° C	30.4	31.8	3.6
<u>Combined inoculations</u>			
20° C	47.0	31.8	1.2
30° C	42.0	35.7	2.3

The effects that temperature, light, nutritional status and moisture conditions have on the rate of sugarcane rust development on a field scale and on an individual plant basis need more detailed study. Determination of the latent period of the pathogen requires daily observation of the same infection sites. The potential for long latent period as a component of resistance in cereals has been documented (8) and could have significant impact on the epidemiology of sugarcane rust. A measurable range of variation in latent period among selections used in breeding will allow breeders to utilize this character in breeding resistance into the germplasm. Measurement of the variation in latent period among sugarcane cultivars will determine whether it can be used as a selection criterion.

The inoculation technique could be used to quantify differential interactions of the host and pathogen among sugarcane cultivars and between isolates of the pathogen. Possibly, variants in the pathogen population in the field could be identified and temporal changes evaluated. The primary problems in this and in similar experiments have been adequate control of environmental factors and a consistent source of inoculum of reasonable viability.

Sugarcane rust incidence decreases in the summer months in Florida; temperature is believed to be strongly related (4). The germination rate of spores collected in the field varies considerably, even during periods that are most favorable for disease development. The influence of temperature and moisture and their role in maintenance of an epidemic are not understood and require more detailed investigation.

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## NEMATOCIDE INCREASES SUGARCANE YIELDS

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Dear Dr. Bond,

This is to inform you of receipt and acceptance of your abstract(s) for inclusion in the Third International Nematology Congress. It is included in:

Poster Session B, Thursday, July 11, 1996

All oral contributions for this Congress are invited papers only. All others are poster presentations. Your abstract will be published in the meeting program as well as the December 1996 issue of NEMATROPICA. Thank you for your contribution.

Sincerely,

*R. Rodriguez-Kabana*

R. Rodriguez-Kabana  
Program Committee Chairman, THINC

AT

variations and nematode assays, from near Edgard, be under stress from nematode attack. Objectives ent with a nematicide and to measure effects of the cted during 1987-89 in a small plot field experiment or three successive years in two varieties of stubble

a side of the rows at the rate of 20 pounds per acre pounds of sugar per acre. At present crop values, of approximately \$83 to \$115 per acre, less present

studies in a Convent fine sandy loam soil were root- hich together comprised 66% of all plant parasitic numbers included stunt (*Tylenchorhynchus*), stubby- enchus) and spiral (*Helicotylenchus*) nematodes, in

magnitude of the nematode problem in Louisiana matodes, and how these interact with different cane nd nematicide treatments. It is believed that further sts.

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g sugarcane cause some destruction of the roots and n regarding their importance in the root-rot complex

Birchfield studied nematodes in sugarcane in Louisiana. He reported in 1953 that a species of lesion nematode (*Pratylenchus* sp.), common on the roots of sugarcane, apparently caused injury to the plant (2). He and coworkers reported on the pathogenicity of certain nematodes to sugarcane (1, 6). In 1969, he wrote that 14 species of plant-parasitic nematodes are associated with sugarcane in Louisiana (4). He summarized, in a review article in 1984, much of the practical knowledge of nematode parasites of sugarcane (5).

In 1965, Birchfield reported studies of the effects of soil fumigation and organic amendments on nematodes and sugarcane yields in Louisiana (3). He stated that early attempts to control sugarcane nematodes were disappointing due partly to the difficulty of fumigating heavy soils. However, in later studies (1966-68) he consistently demonstrated, for three consecutive years, significant increases in yields of cane and sugar per acre from the application of nematicides. By applying a 10% granular formulation of aldicarb in the open furrow at planting, he increased per acre yields in the plant cane crop by an average 6.8 tons of cane and 1,170 pounds of sugar for a substantial 24% three year average yield increase (4).



The effects that temperature, light, nutritional status and moisture conditions have on the rate of sugarcane rust development on a field scale and on an individual plant basis need more detailed study. Determination of the latent period of the pathogen requires daily observation of the same infection sites. The potential for long latent period as a component of resistance in cereals has been documented (8) and could have significant impact on the epidemiology of sugarcane rust. A measurable range of variation in latent period among selections used in breeding will allow breeders to utilize this character in breeding resistance into the germplasm. Measurement of the variation in latent period among sugarcane cultivars will determine whether it can be used as a selection criterion.

The inoculation technique could be used among sugarcane cultivars and between isolates of in the field could be identified and temporal changes experiments have been adequate control of environmental reasonable viability.

Sugarcane rust incidence decreases in the strongly related (4). The germination rate of spores that are most favorable for disease development. The maintenance of an epidemic are not understood and

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## NEMATICIDE INCREASES SUGARCANE YIELDS

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### ABSTRACT

This work was undertaken because of field observations and nematode assays, from near Edgard, Louisiana, in 1985, which suggested that sugarcane might be under stress from nematode attack. Objectives of the work were to determine crop response to soil treatment with a nematicide and to measure effects of the latter on nematode populations. These studies were conducted during 1987-89 in a small plot field experiment in which soil treatment with aldicarb (Temik) was made for three successive years in two varieties of stubble sugarcane.

A single application of Temik 15G banded on each side of the rows at the rate of 20 pounds per acre (22 kg/ha) increased yields by 573 (8.5%) to 797 (16.1%) pounds of sugar per acre. At present crop values, these responses to treatment would translate into profits of approximately \$83 to \$115 per acre, less present treatment costs of \$59 for the nematicide.

The two most abundant nematodes found in these studies in a Convent fine sandy loam soil were root-knot (*Meloidogyne*) and ring (*Criconebella*) nematodes, which together comprised 66% of all plant parasitic nematodes found. Other types which were found in smaller numbers included stunt (*Tylenchorhynchus*), stubby-root (*Paratrichodorus*), lance (*Hoplolaimus*), lesion (*Pratylenchus*) and spiral (*Helicotylenchus*) nematodes, in decreasing order of abundance.

Further studies are needed to determine the magnitude of the nematode problem in Louisiana sugarcane, the relative importance of different kinds of nematodes, and how these interact with different cane varieties, age of crop, soil types, possible rotation crops, and nematicide treatments. It is believed that further research may result in significant reduction of control costs.

### INTRODUCTION

In 1955, Edgerton wrote that nematodes attacking sugarcane cause some destruction of the roots and aid the root-rotting organisms, but that definite information regarding their importance in the root-rot complex was not available at that time (7).

Birchfield studied nematodes in relation to sugarcane in Louisiana. He reported in 1953 that a species of lesion nematode (*Pratylenchus* sp.), common on the roots of sugarcane, apparently caused injury to the plant (2). He and coworkers reported on the pathogenicity of certain nematodes to sugarcane (1, 6). In 1969, he wrote that 14 species of plant-parasitic nematodes are associated with sugarcane in Louisiana (4). He summarized, in a review article in 1984, much of the practical knowledge of nematode parasites of sugarcane (5).

In 1965, Birchfield reported studies of the effects of soil fumigation and organic amendments on nematodes and sugarcane yields in Louisiana (3). He stated that early attempts to control sugarcane nematodes were disappointing due partly to the difficulty of fumigating heavy soils. However, in later studies (1966-68) he consistently demonstrated, for three consecutive years, significant increases in yields of cane and sugar per acre from the application of nematicides. By applying a 10% granular formulation of aldicarb in the open furrow at planting, he increased per acre yields in the plant cane crop by an average 6.8 tons of cane and 1,170 pounds of sugar for a substantial 24% three year average yield increase (4).

Sugarcane growers in Louisiana have long had trouble maintaining efficient production in ratoon cane for more than two or three years. Nematodes probably are one of several factors involved in this "running out of the stubble." Numerous studies have been reported during the past two decades from various parts of the world which indicate that nematodes are a widespread problem on sugarcane.

In late summer of 1985, approximately 2,400 nematodes were found in a 500 cc sample of sandy loam soil at Edgard, Louisiana, where ratoon sugarcane was obviously under severe stress. Another soil sample, taken less than 50 feet away from an area in which cane plants appeared relatively healthy, contained only approximately 500 nematodes. Limited observations in the same area the following year indicated that no visible response in sugarcane growth resulted from soil treatment with a nematicide, and that nematode populations may have rebounded following treatment to levels higher than those in untreated soil. Limited sampling also indicated that nematode numbers may increase with age of the crop.

This paper reports results from studies conducted on Gold Mine Plantation at Edgard, Louisiana, during three years (1987-1989) to determine potential benefits from nematode control in stubble sugarcane.

## MATERIALS AND METHODS

In the spring of 1987, a field of first ratoon cane was selected for experimental studies. The soil type was a Convent fine sandy loam. Plots three rows wide (18 ft or 6.3 m) by 50 feet (15.25 m) long were measured in two different sugarcane varieties. Ten adjacent plots were staked out in three rows of CP 72-370 sugarcane near one side of the field, and ten plots were established in the same way in three rows of the variety CP 72-356 near the other side of the field at least a hundred yards (92m) distant. Each line of plots began at a distance of 25 ft (7.6 m) into the field from the headland. The first plot in each line was designated to be treated with nematicide and alternate plots were designated as untreated checks. All data were analyzed statistically by t-test for paired comparisons between adjacent treated and untreated plots. Although treatments were not randomly assigned to plots, it is believed that the experimental design accomplished the purpose of randomness.

Aldicarb (Temik 15G) was applied in the treated plots 4/22/87 and 5/13/89 by hand from a quart-size fruit jar with holes punched in the top. The granules were applied at the rate of three pounds of active ingredient (20 pounds of 15G) per acre (2.7 kg active ingredient per hectare) in a band approximately eight inches (20 cm) wide in the off-bar furrow on each side of the row, after which the furrow was closed by disks bringing dirt from the middle to the top of the row. This nematicide was applied 4/26/88 at the same per acre rate, but in a 36-inch (0.9 m) band over the row with off-bar furrows on each side of the row approximately 28 inches (0.7 m) apart. This unfortunately resulted in an undetermined but considerable amount of nematicide not getting covered or incorporated with soil for the second ratoon crop.

Sugarcane in experimental plots was grown under recommended cultural practices and harvested with a single-row harvester 11/8/87, 11/9/88, and 10/18/89. Cane from the middle 32 feet (9.76 m) of each plot was weighed using a tractor-mounted hydraulic weigh cell. A random sample of 15 stalks was taken from each plot, weighed, and analyzed for juice quality at the USDA Laboratory, Houma, Louisiana. Tons of cane per acre, pounds of sugar per ton of cane (CRS), and pounds of sugar per acre were calculated for each plot by standard methods.

Pre- and post-treatment soil samples were taken each year for nematode assay. Samples were composed of 12 to 20 cores taken to a depth of nine inches (23 cm) with a standard soil probe. Samples were always taken among live sugarcane roots from the middle row or rows of the plot and spaced approximately equidistantly apart, but never closer than six feet (1.83 m) from plot borders. The soil cores were mixed by hand in a bucket, from which approximately one and one-half pints (0.7 liter) of soil were transferred to a wax-lined, paper bag for delivery to the laboratory where only plant parasitic nematodes were identified and counted.

## RESULTS AND DISCUSSION

Table 1 shows that soil treatment with aldicarb in 1987 and 1989 increased yields in first and third ratoon sugarcane by averages of 573 (8.5%) and 797 (16.1%) pounds of sugar per acre, respectively. These responses to treatment were statistically significant at  $P = .01$ , and suggest a greater response in third than in first ratoon.



The data also indicate a greater response to treatment in the variety CP 72-370 than in CP 72-356. Assuming an approximate value to the grower of 14.5 cents per pound of sugar, the above yield responses would translate into profits from nematicide treatment of \$83 to \$115 per acre, less treatment costs. Similar calculations, based on Birchfield's earlier results with aldicarb (4), would suggest larger profits of almost \$170 per acre, less treatment costs.

Table 1. Pounds of sugar per acre from two sugarcane varieties in aldicarb treated and untreated plots, Edgard, Louisiana, 1987-1989.

Crop age	Variety	Treated	Untreated	Difference
1st ratoon	CP 72-370	6878	6117	761 *
	CP 72-356	7639	7254	385
	Mean	7259	6686	573 **
3rd ratoon	CP 72-370	5551	4716	835 *
	CP 72-356	5964	5206	758 **
	Mean	5758	4961	797 **

\* Significant by t-test at 5% level.

\*\* Significant by t-test at 1% level.

Temik 15G was used at the maximum label rate of 20 pounds per acre (22.5 kg/ha) which presently might cost in the neighborhood of \$59/acre. However, similar results might be obtained with a minimum rate of Temik costing approximately \$41/acre. Also, the costs of label recommended rates of other nematicides such as carbofuran (Furadan) and ethoprop (Mocap), which are presently labelled for use on sugarcane, would be less. For example, recommended label rates of Furadan 15G presently would range from approximately \$22 to \$44 per acre. Similarly, per acre costs of Mocap 15G might range from approximately \$26 to \$52. It is hoped that further research may reveal an equally effective and less expensive treatment.

Table 2 shows that soil treatment with aldicarb increased yields of first and third ratoon sugarcane by averages of 2.2 (7.4%) and 2.8 (11.4%) tons of cane per acre, respectively; these yield increases were statistically significant at  $P = .05$  and  $P = .01$ , respectively. Again the data suggest a greater response in third than in first ratoon cane. CP 72-370 also appeared to respond to treatment more than CP 72-356 in tons of cane produced.

Table 2. Tons of cane per acre from two sugarcane varieties in aldicarb treated and untreated plots, Edgard, Louisiana, 1987-1989.

Crop age	Variety	Treated	Untreated	Difference
1st ratoon	CP 72-370	30.6	27.6	3.0
	CP 72-356	33.0	31.7	1.3
	Mean	31.8	29.6	2.2 *
3rd ratoon	CP 72-370	25.0	21.9	3.1 *
	CP 72-356	29.8	27.3	2.5 *
	Mean	27.4	24.6	2.8 **

\* Significant by t-test at 5% level.

\*\* Significant by t-test at 1% level.

Table 3 shows that soil treatment with aldicarb gave relatively small and non-significant increases in pounds of sugar per ton of cane (CRS) in the first ratoon crop. In third ratoon, an average increase of 8.0 (3.9%) pounds of sugar per ton was statistically significant at  $P = .01$ . However, it is obvious from the data in Tables 1-3 that most of the increases in sugar production are due more to increases in cane tonnage than in sugar per ton.

Table 3. Pounds of sugar per ton of cane (CRS) from two sugarcane varieties in aldicarb treated and untreated plots, Edgard, Louisiana, 1987-1989.

Crop age	Variety	Treated	Untreated	Difference
1st ratoon	CP 72-370	225	221	4.0
	CP 72-356	231	229	2.0
	Mean	228	225	3.0
3rd ratoon	CP 72-370	222	214	8.0 *
	CP 72-356	200	191	9.0 **
	Mean	211	203	8.0 **

\* Significant by t-test at 5% level.

\*\* Significant by t-test at 1% level.

The increases in production of sugar per acre which were obtained by soil treatment with aldicarb in first and third ratoon cane were not as great as those reported earlier by Birchfield (4), using the same nematicide in plant cane. However, his results were obtained at a different time and place, with a different sugarcane variety (CP 44-101), and in a heavier soil of a different type.

We obtained data on crop yields and nematodes in replicated plots of first, second, and third ratoon cane during 1987, 1988, and 1989, respectively. However we deleted the 1988 crop response data from our tables because they indicated no substantial nor significant responses to treatment, and because the treatment was made in a manner which resulted in much of the toxicant remaining on the soil surface without being incorporated.

Although yield data for the second ratoon crop of 1988 are not reported here, a stand count, made 4/15/88, eleven days before the nematicide was applied to the treated plots that year, showed an average 16.6% more shoots in plots treated with aldicarb the previous spring than in untreated plots. This difference was statistically significant at  $P = .05$ . While significant yield responses to treatment did not occur in 1988, this stand difference may reflect a carry over effect which could be cumulative over several successive years of soil treatment. More attention should be given to possible effects of soil treatment on stands in future studies.

Soil sampling for nematodes gave highly variable results with no significant differences which could be reasonably associated with treatment effects. A major objective of future studies must be to obtain better data on nematodes to permit reasonable assurance that yield responses are actually due to reductions in nematode numbers, although these may be of short duration.



Although nematode data from treated and untreated plots were not helpful in explaining treatment effects, a considerable effort was made to identify and count nematodes. A total of 84,143 nematodes were estimated to be present in all soil samples assayed. This total was composed of nematodes of the following genera in the proportions indicated:

<i>Meloidogyne</i> (root-knot)	37.1%
<i>Criconebella</i> (ring)	29.1%
<i>Tylenchorhynchus</i> (stunt)	15.4%
<i>Paratrichodorus</i> (stubby-root)	8.3%
<i>Hoplolaimus</i> (lance)	6.0%
<i>Pratylenchus</i> (lesion)	2.6%
<i>Helicotylenchus</i> (spiral)	1.4%

Root-knot (*Meloidogyne*) nematodes were always the most abundant in the studies reported in this paper which were conducted in a Convent fine sandy loam soil. Birchfield's outstanding yield responses to soil treatment with aldicarb were obtained in a Mississippi alluvial soil of the Mhoon series which was infested predominantly by nematodes of the genera *Tylenchorhynchus*, *Pratylenchus*, and *Trichodorus* (4)

In his 1984 review of nematode parasites of sugarcane, Birchfield states that root-knot nematodes (*Meloidogyne* spp.) cause the most economically important nematode disease of sugarcane worldwide, and that damage by lesion nematodes (*Pratylenchus* spp.) is believed to be second only in importance to that caused by root-knot nematodes. He believes that lance nematodes (*Hoplolaimus* spp.) also cause economic losses on sugarcane. He states that economic damage by stunt (*Tylenchorhynchus* spp.) and spiral nematodes (*Helicotylenchus* spp.) is not great, that the amount of damage to sugarcane by stubby-root nematodes (*Paratrichodorus* spp.) is unknown, and that root symptoms caused by the last mentioned group are not obvious. He mentions other nematodes reported from sugarcane, including members of the ring nematode group (*Criconebella* spp.) of which he states that their economic importance on sugarcane has not been determined (5).

Although ring nematodes were the second most abundant nemas present in our study, they may not have been second in importance since different species vary considerably in their ability to damage a crop. Also, endoparasitic species, such as the lesion nematodes (*Pratylenchus*) may be more important than is suggested by their relative abundance in our studies. Such migratory endoparasitic worms may be largely missed by sampling only soil at times when large numbers of these nematodes may be inside roots.

## CONCLUSIONS

From these studies, the following conclusions are drawn:

1. Soil treatment with aldicarb in ratoon sugarcane increased yields by 573 (8.5%) to 797 (16.1%) pounds of sugar per acre. At present crop values, these responses to treatment would translate into profits of approximately \$83 to \$115 per acre, less treatment costs.
2. The two most abundant nematodes found in these studies in a Convent fine sandy loam soil were root-knot (*Meloidogyne*) and ring (*Criconebella*) nematodes, which comprised 66% of all nematodes counted. The relative abundance of different species of nematodes should be expected to vary with soil type.
3. Further studies are needed to determine the distribution and magnitude of the nematode problem on Louisiana sugarcane. These should include objectives to determine the relative importance of different kinds of nematodes and how they interact with different cane varieties, age of crop, soil types, possible rotation crops, and nematicides. Nematicide studies should include different rates and methods of application.

## ACKNOWLEDGEMENTS

We gratefully acknowledge the assistance and interest of Mr. Stan Rodrigue, David Rodrigue, and other members of the staff of Gold Mine Plantation, Inc. at Edgard, Louisiana, without whom these studies might not have been done. We are grateful for assistance given during harvesting of plots by Windell Jackson, agronomist, American Sugar Cane League and Donnie Garrison, agronomist, USDA, and for the use of the tractor mounted hydraulic weigh cell loaned us by the USDA Sugarcane Research Station at Houma, Louisiana.

Mr. Charles Overstreet, nematologist, Louisiana Cooperative Extension Service of Louisiana State University in Baton Rouge, provided valuable assistance by performing nematode assays of soil samples collected during 1985-1987. During 1988-1989, nematodes were identified and counted by Dr. Calvin Orr, A & L Agricultural Laboratories, Inc., Lubbock, Texas.

The Nicholls College Foundation contributed approximately \$800 for nematode assays by a commercial laboratory. The Nicholls State University Research Council partially supported this work by a \$1600 research grant awarded for the last year of the studies reported. Nicholls State University contributed an additional \$1400 to permit the senior author to attend a nematode identification short course at Clemson University. Long Pest Management, Inc. of Thibodaux, Louisiana, contributed uncounted hours of work and travel expenses to and from the field. Thanks are due Mr. Robert Millet, Manager of Helena Chemical Company, Thibodaux, Louisiana, for supplying the Temik 15G nematicide used in these studies.

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## MANUFACTURING PAPERS

### THE IMPORTANCE OF GOOD CANE PREPARATION IN EXTRACTION PLANTS

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#### ABSTRACT

The innovations in cane preparation has significant benefits in cane processing for the sugar industry.

For example, the stabilization of feed throughout the mill train, regardless of conditions, results in lower pol % in the final bagasse, higher cane tonnage, better tramp iron detector (magnet) horsepower performance, less wear and horsepower demands on existing mills and with a superior extraction yield. The new improved shredding methods using heavy duty equipment to obtain over 90% preparation index (P. I.), while still maintaining an acceptable fibre length, are listed and explained in line with economic considerations for a fast payback. Retrofitting existing tandem installations to suit various mill lay-outs, carriers, and conveyers are also discussed.

#### INTRODUCTION

Cane extraction factories especially those that have a high pol final bagasse of 3% and over could derive considerable advantages from good cane preparation, yielding a higher extraction largely by using a shredder for the final cane preparation to ease the task of the extraction plant.

With the ever increasing fibre % in cane, the object and importance of a shredder is to complete the preparation of the cane directly following the cane knife or knives. It is now a well established fact that this method (P. I.) gives up to 90% open cells, whereas milling trains with cane knives only, reaches an average of 70% open cells.

#### New concepts

Sugar mill engineers in the past have had very disappointing results with shredders. They experienced difficulty in feeding the mills because of chokes, slippage, etc., especially with finely prepared cane. These problems have been eliminated today with advanced technology, such as:

- a) Mill rollers roughened by welding methods
- b) Vertical high chute (Donnelly) type
- c) The adaption of a press roll (feed roll) to the existing conventional 3-roll mills
- d) The more advanced shredder that gives a fibre length of 4" to 5" ensuring the bagasse mat to be well interlaced to facilitate a good constant feed to the mills; thereby maintaining weight and volumetric feed rates closer to the optimum values necessary to sustain a constant imbibition/fibre and fibre/scribed volume ratios. The selection of the type of shredder is of the uttermost importance because of fibre length. The 4" to 5" fibre length shredder provides a better grip, therefore, improving on the earlier problem areas of choking and slippage.

#### Shredder types and adaptations

There are many different types of shredders too numerous to explain in this paper. We therefore selected two well known and proven shredders, demonstrating lay-outs with high speed belt carriers and magnet prior to the first mill.



This shredder requires a minimum height from the floor level of 13 ft with a cane knife height of 22 ft installed over it to constantly feed cane from the main carrier into the shredder below. Unfortunately, there are some existing factory lay-outs which cannot take advantage of this shredder because of its height, and distance.

TYPICAL HEAVY DUTY  
SHREDDER  
P.I. - 90 %

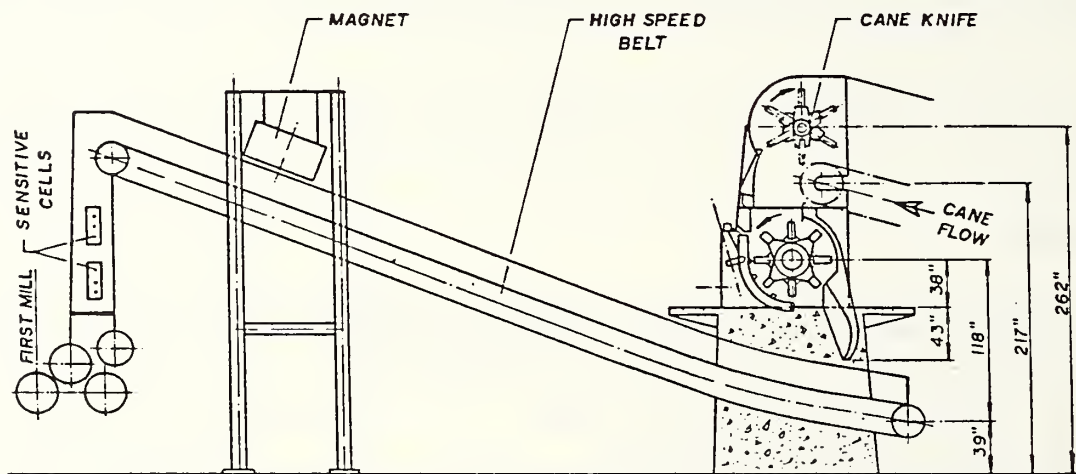


Figure 1. The installation of a shredder of 90% P. I.



This shredder can easily be adapted directly into any existing main cane carrier with a simple foundation to support the shredder and its drive. The ideal arrangement is to have a high speed belt conveyor of 300 feet/min installed after the shredder:

- a) To reduce the shredded cane mat thickness, therefore allowing the tramp iron detector (magnet), which is installed above the belt conveyor, to work more efficiently.
- b) Due to the reduced cane mat thickness being fed to the 1st mill through a vertical Donnelly chute, which in turn has a series of sensors to control the speed of the 1st mill and the cane carrier, a constant bulk density of shredded cane, well compacted to the first mill is achieved; therefore, eliminating choking, regardless of cane conditions and variations of fibre.

**TYPICAL HEAVY DUTY  
SHREDDER  
P.I - 85 %**

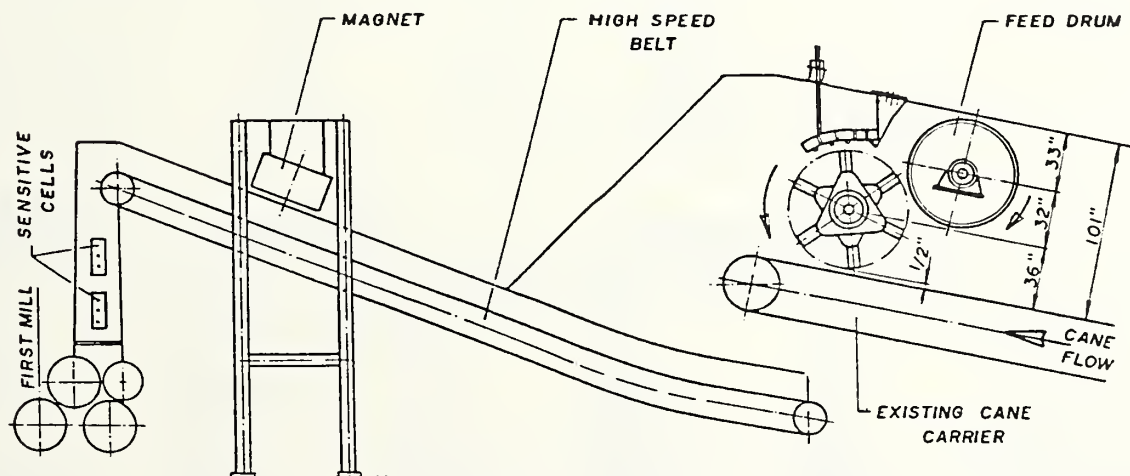


Figure 2. The installation of a shredder of 85% P. I.

**Performance data (pol % and tonnage)**

The following tables clearly demonstrate the improved performance achieved in mill trains after the installation of a shredder, and a shredder with press rollers. Tables 1 and 2 have a preparation index (P. I.) of 85 %.

Table 1. Usina/distillery Alcidia - S. P. - Brazil.

Period	<u>Without shredder</u>		<u>With shredder</u>		<u>With shredder</u>
	1982	1983	1984	1985	+ press rollers 1988
T. C. H. (U. S. Ton)	220	215	260	262	320
Nos. and mill size	6 x 66"	6 x 66"	6 x 66"	6 x 66"	6 x 66"
Fibre % cane	13.50	13.30	13.3	14.00	13.80
Pol % final bagasse	3.90	4.02	3.4	3.06	2.10
Reduce extraction	91.00	91.40	92.2	92.70	95.80
Imbibition % cane	32.00	34.20	32.3	31.70	30.90
Preparation index	70.00	70.00	84.0	84.50	84.50

Table 2. Usina/distillery Vale do Rosario - S. P. Brazil.

Period	<u>Without shredder</u>		<u>With shredder</u>		<u>With shredder</u>
	1982	1983	1984	1985	+ press rollers 1988
T. C. H. (U. S. Ton)	230	225	290	310	350
Nos. and mill size	6 x 66"	6 x 66"	6 x 66"	6 x 66"	6 x 66"
Fibre % cane	12.90	12.80	13.10	13.00	13.20
Pol % final bagasse	4.01	3.83	2.74	2.71	2.20
Reduce extraction	90.70	91.01	92.90	94.00	94.90
Imbibition % cane	35.00	33.00	33.10	35.10	36.40
Preparation index	70.00	70.00	85.00	84.00	84.50

Table 3. Usina/distillery Guarani - S. P. - Brazil.

Period	Without shredder		With shredder		With shredder + press rollers
	1982	1983	1984	1985	1988
T. C. H. (U. S. Ton)	275	270	326	332	375
Nos. and mill size	5 x 72"	5 x 72"	5 x 72"	5 x 72"	5 x 72"
Fibre % cane	12.90	13.20	13.27	13.10	13.60
Pol % final bagasse	3.50	3.40	2.40	2.55	2.00
Reduce extraction	92.20	92.10	94.30	94.50	95.70
Imbibition % cane	32.50	34.00	32.10	32.00	34.10
Preparation index	70.00	70.00	89.00	89.50	89.00

Table 4. Usina/distillery Santa Elisa - Brazil.

Period	Without shredder		With shredder		With shredder + press rollers
	1982	1983	1984	1985	1988
T. C. H. (U. S. Ton)	350	360	480	450	470
Nos. and mill size	6 x 84"	6 x 84"	5 x 84"	5 x 84"	5 x 84"
Fibre % cane	13.05	12.90	13.00	13.20	13.00
Pol % final bagasse	3.20	3.40	2.60	2.18	1.96
Reduce extraction	93.60	93.40	94.90	95.50	96.00
Imbibition % cane	35.00	34.80	28.70	28.90	28.10
Preparation index	70.00	70.00	90.00	89.00	89.50

Continuing the discussion of the above tables, some interesting results were achieved at the Santa Elisa Distillery, a 6 mill tandem. One mill was removed and a shredder with press rollers was installed in the same period. See Table 4 for effects. Summarizing tables 1 to 4, it appears that a good relative performance is associated with mill trains fitted with shredders.

#### Comparisons in Power Consumption

The power consumed by a shredder is mostly recovered through the reduction of the mill load, which in turn allows for the extraction of the maximum of juice, and in some circumstances an existing cane knife set can be eliminated.

Electrically driven, estimated mean power absorbed by a shredder:

85% P. I.      Rotation 630 rpm absorbs 24 HP per T. F. H.  
90% P. I.      Rotation 1200 rpm absorbs 29 HP per T. F. H.

The estimated power saving with a shredder:

- a) The removal of one cane knife set = 12 HP per T. F. H.
- b) A reduction in power per mill = 3 HP per T. F. H.
- c) Mill trains of 6 mills (6 x 3) = 18 HP per T. F. H.

Total HP saving = 12 + 18 = 30 HP per T. F. H.

The above evaluation demonstrates that the energy balance is not affected. To my knowledge, the only illustrated absorbed power test carried out was at the Mount Edgecomb Sugar Mill in South Africa, in 1933, quoted in Emile Hugot Book, page 63, published in 1960. See Table 5.

Table 5.

	Without shredder	With shredder
Amperes taken by 5 mills at 550 volts	1,304	1,100
Amperes taken by shredder	0	175
Total amperes taken	1,304	1,275

#### Costs and returns

The installation cost of a heavy duty shredder is in the region of 320,000 U.S. dollars which is quickly recovered.

The calculations below are based on past sugar factory results in the U. S. A.:

- a) Without a shredder
- b) A shredder with an estimated 1% pol drop in the final bagasse. See Table 6.

Table 6.

	A	B
Pol % cane	12.30	12.30
Fibre %	11.00	11.00
Moisture 51.90	52.00	
Pol % final bagasse	3.50	2.50
Extraction pol %	92.80	94.80
Bagasse % fibre	43.42	43.42
Pol bagasse % cane	0.88	0.63

Expected results calculations:

<u>Bagasse % cane</u>	<u>Pol bagasse % cane</u>	<u>Pol % extraction</u>	<u>Gain % pol</u>
$\frac{11.0 \times 100}{43.42} = 25.33$	$\frac{25.33 \times 2.5}{100} = 0.63$	$\frac{12.3 - 0.63}{12.3} = 94.8$	$0.88 - 0.63 = 0.25$



### Payback

Considering a grinding season of 1,000,000 tons of cane, a total factory recovery of 87%, and one lb of sugar at 20 U. S. cents, the payback will be:

$$\frac{1,000,000 \times 0.25}{100} = 2500 \text{ tons pol per season}$$

$$0.87 \times 2500 = 2175 \text{ tons of sugar per season}$$

$$\frac{2175 \times 2000 \times 20}{100} = 870,000 \text{ U. S. dollars per season}$$

### **SUMMARY**

High milling efficiency is dependant on good prepared cane, especially to enable the first mill to give an extraction of 75%, which will ensure excellent extraction results.

# AUTOMATION OF ANALYSES OF SUGARCANE JUICE SAMPLES<sup>1</sup>

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## ABSTRACT

An electronic scale to determine sample weight and an automatic refractometer and saccharimeter to measure Brix and polarization (Pol), respectively, were interfaced with a desk-top personal computer with two 20 megabyte fixed disk drives, 640 kilobyte (kb) Ram and 5.25 inch 360 kb diskette drive. Each station, where data were entered, had a keyboard with liquid crystal display (LCD) and provisions for accommodating a bar-code reading wand. System and application software were developed to support control boards and terminals, to drive various data acquisition stations, to retrieve data from individual stations and to format results for storage in a master data file. Data for each sample included a researcher identification number, experiment number, plot number, observed Brix, temperature, Pol, corrected Brix, apparent sucrose and purity, yield of theoretical recoverable sugar per ton of cane (TRS), sample weight, number of stalks in the sample and mean stalk weight. These data were stored in the master file or printed automatically. Automation of the juice quality laboratory should increase efficiency of technicians by minimizing errors of observation, entry and transcription of data and provide a data base ready for statistical analyses.

## INTRODUCTION

One of the functions of the Sugarcane Research Unit's juice quality laboratory is to analyze 5-10,000 sugarcane samples annually for cane and juice quality (2). These data are obtained from 5-15 stalk samples harvested from field experiments brought to the laboratory for analyses. Each sample is weighed and juice extracted using a 3-roller sample mill or prebreaker/hydraulic press. This juice is then analyzed for observed Brix, temperature and polarization (Pol) (1). From these data, the yield of theoretically recoverable sugar per ton of cane (TRS) is calculated for each sample using equations described by Legendre and Henderson (3).

These methods are time consuming because laboratory technicians have to perform the tests as well as record the data at each of three test stations, often resulting in data entry errors. Data are later collated and entered into a desk-top personal computer (PC). In addition, the observed data and calculated results are not maintained permanently on disk storage. Consequently, each researcher must re-enter these results for statistical analysis.

Three solutions to these problems were proposed: 1) Devise a computer interface between the lab scale, refractometer and saccharimeter directly to the personal computer; 2) Provide a method to eliminate the manual entry of a plot identification number (ID) and sample number; 3) Accumulate the input data and results of each day's samples on disk storage and develop software to extract and format results for statistical analysis. This paper describes the implementation of these solutions.

## Hardware

The data acquisition system developed for the juice quality laboratory consisted of three instruments, a scale to measure the weight of sample, a refractometer to measure Brix and a saccharimeter to measure polarization, and their data entry terminals (Figure 1). Interface cards were added to the personal computer (PC) to communicate with the laboratory equipment and its individual data terminal since the output of the scale and the saccharimeter were in binary coded decimal (BCD) and the refractometer was in RS/232 protocol.

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<sup>1</sup> Mention of a trademark or proprietary product does not constitute a guarantee or warranty of the product by the U.S. Department of Agriculture, and does not imply its approval to the exclusion of other products that may also be suitable.

Additional hardware to complete the automation included a 4-port RS/232 serial input/out (I/O) board to communicate with the data terminal and the refractometer, a digital I/O board to communicate with the scale and saccharimeter and three data terminals to communicate with the operators.

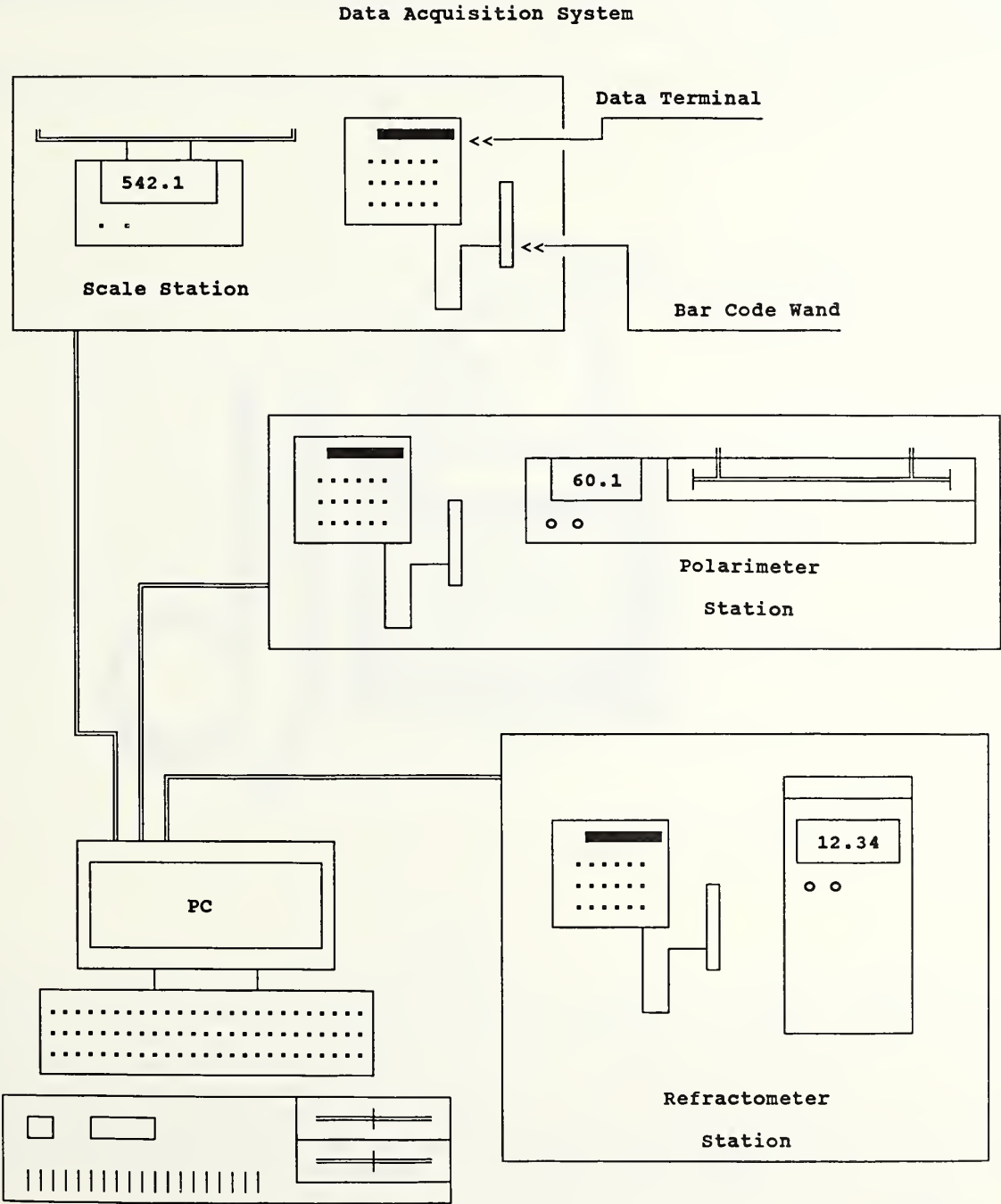


Figure 1. Lab automation hardware.

The self-contained display terminals were used at each instrument for information exchange with the PC. This device is shown in Figure 2. The terminal consisted of a 24-key, sealed membrane keyboard for operator input to the PC or, depending upon the mode of operation, for local presentation on the display. There were eight special function keys (F1 through F8) which may be assigned appropriate values, i.e., yes, no, etc., when through a displayed prompt that answer is appropriate. The display was a 2-line, 48-character electro-reflective liquid crystal display (LCD) which could display the 96 standard ASCII characters. Its functions were to present visual prompts as well as feedback of the data values obtained for the laboratory equipment. Each terminal had provisions for accommodating a hand-held optical wand for reading barcode labels. The data decoded by the wand appeared on the display screen at the cursor position and was transmitted out the communication port to the PC. Code 39 barcode was chosen for use over the Universal Product Code because it could encode alphabetic as well as numeric data.

An attached printer was used to list data received from the laboratory equipment and data terminals, and to list end-of-day results of analyses.

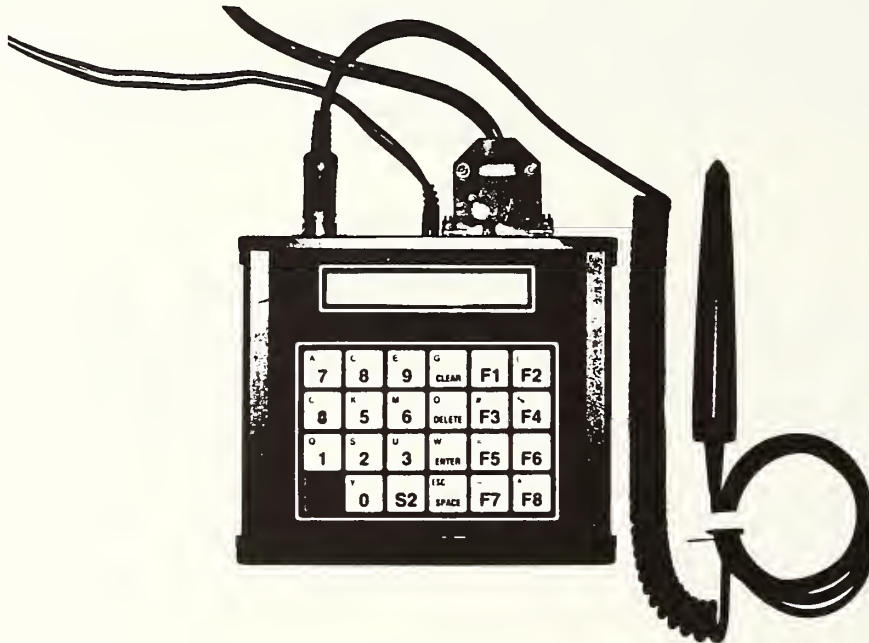


Figure 2. Data Terminal and Bar Code Wand

#### Software

All application software was programmed in Microsoft® Quick Basic. Sealevel Systems, Inc. supplied the necessary software to allow the programmer to interface the controller program to the board and to support more than two communication ports on the PC. The software package incorporated to manage the master and transaction files was Btrieve® from Novell, Inc. Software used to create menus, data entry screen images and the controller programs included Screen Sculptor®, Softcode®, Flash-Up® and Speed Screen® from Software Bottling of New York. These programs were loaded prior to the application and remained resident during execution. The software package used as a communications manager with the digital I/O board and background RS/232 board as well as to manage and intercept programs from the programmer was Combuff from Commtech, Inc. Additionally, software to print bar code labels was obtained from Worthington Data.

All programs in the application were menu driven and hierarchical, one menu lead to another menu until the desired function was found. Figure 3 illustrates the relationship of one menu to another in the application.



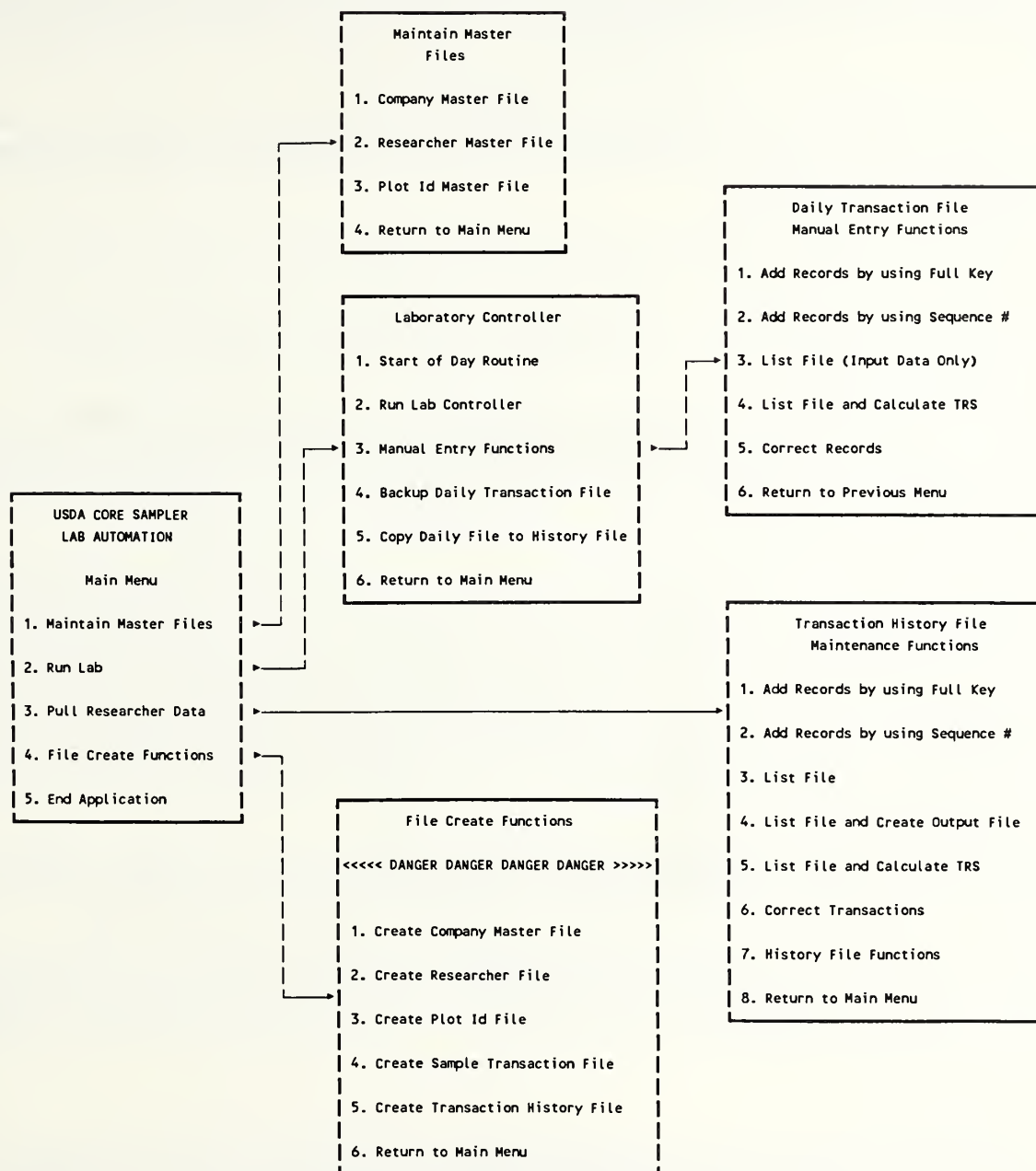


Figure 3. Major menus of lab automation application.

### Laboratory Control Program

Paramount to the laboratory automation was the controller program. This program interfaced laboratory equipment, the three data terminals and the printer with the computer. Test stations functioned independently of one another so data could be simultaneously entered at a station regardless of what was happening at other stations.

Data were entered at each station only after the technician was prompted by the computer. By entering data interactively at each terminal and by storing the progress of each exchange, the effect of simultaneous response was maintained. The controller program does not wait for a response but instead looks to see if any other terminal has input data ready.

Data are printed when a jargon is completed at a test station and data are verified. This was done to provide a record of a day's operation in the event of hardware or software failure that might destroy the test data.

The cathode ray tube (CRT) of the computer shows the progress of the controller program at each station, with the results of the last completed test displayed. This screen is illustrated in Figure 6.

It was necessary to create and build several files to manage the information gathered by the laboratory control program. There were three types used in this application: 1) master files; 2) transaction files; and, 3) temporary files. Master files were used to contain information gathered prior to the beginning of the sampling season. Transaction files contained the results to date of the samples taken each day. Temporary files were used during the processing of the samples and were created anew each time they were needed.

There were three master files used in the laboratory control program: 1) The lab master file contained information specific to the entire application, including the current day and date, as well as the specific printer control codes used during analyses. 2) The researcher file contained the name of each researcher submitting samples to the laboratory. This file was indexed and accessed using a key consisting of the initials of the researcher. 3) The plot identification (ID) file contained a record for each plot sampled. This file was also indexed and accessed using one of two keys. The first key consisted of three subkeys; the researcher ID, the test number and the plot number and was used to sort the results by researcher. The second key was simply a sequence number that was used instead of the first key when an individual sample that was not part of a specific test was brought into the laboratory for analysis.

Each record of the plot ID file contained information specific to that plot including: variety/clone number, milling factor (called varietal correction factor or simply VCF), crop year, i.e., plant, first ratoon, etc., replication number, soil type, sample size, type of test and remarks (4 lines of 40 characters each).

Figure 4 details sample screen images and information for each of the master files. Figure 5 illustrates the series of menus which manage the three master files. The menu label "Backup/Restore/Recover Functions" enabled the operator to save and restore the master files to diskette(s). This menu also allowed the operator to recover and rebuild damaged files.

### Manual Entry Programs

Included in the application were a series of programs to enter the laboratory sample data manually. The juice laboratory has backup test equipment which does not have computer interface features and could be used in the event of equipment failure. These functions were also used to add data from samples that were omitted. Provisions were included to correct or delete samples as well as to list the day's results.

### Crop-to-Date File

At the end of the day all test data were listed along with the calculated value of the yield of theoretical recoverable sugar per ton. This value was checked for accuracy and, if necessary, the manual functions were used to correct or delete any entries. After all entries were verified the transaction file for that day was backed up on diskette and then merged with a file containing all previous days' samples. This crop-to-date file was backed up as well at the end of the day.

Setup Master Printer Control Screen:

Master File and Printer Configuration	
1. Company Name..... United States Department of Agriculture	
2. Date..... 09/18/88	
3. Day..... 4	
Bell..... 7	Start Double Wide Print.... 14
Line Feed..... 10	Stop Double Wide Print..... 20
Form Feed..... 12	Start Compressed Print..... 15
Carriage Return..... 13	Stop Compressed Print..... 18
Escape..... 27	Set Form Length..... 67
6 Lines/Inch..... 50	Set Perforation Skip..... 78
8 Lines/Inch..... 48	Disable Perforation Skip.... 79

Correct Researcher Record Screen:

Researcher File	Date: 03/23/89
Correct Records	
Researcher Id: WHT	Time: 1:47:25
1. Researcher Name..... William H. Thibaut	
1234567890	
2. Code..... 1234567890	
3. Delete Record (Y/N)...	

Correct Plot Id Record Screen:

Plot ID File	Date: 03/23/89
Correct Records	
Plot Id: WHT-123- 1	Time: 1:47:55
1. Variety..... cp99187	
2. VCF..... 1.023	
3. Ratoon..... 1	
4. Replication Number..... 1	
5. Soil Type..... BLACK	
6. Nominal # Stalks/Test..... 15	
7. Type of Tests..... maturity	
8. Remarks.....	
9. Delete Record? Y on N.....	

Figure 4. Screen images of master file records.

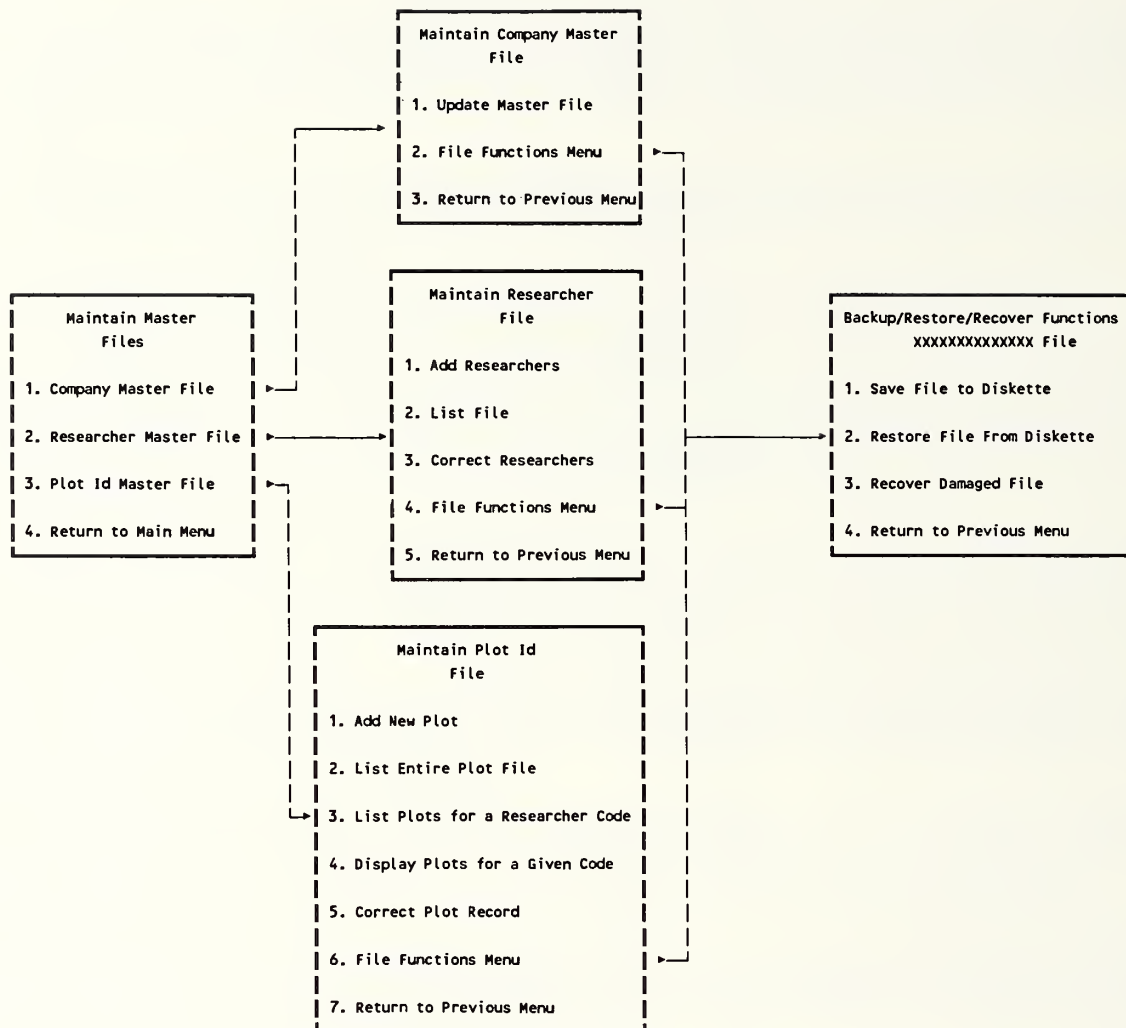


Figure 5. Master file maintenance menus.



Start of Day Screen:

Master File and Printer Configuration	
1. Company Name.....	United States Department of Agriculture
2. Date.....	09/18/88
3. Day.....	4

Lab Controller Status Screen:

Date 09/18/88	Core Sampler Date Acquisition System	Time 13:52:21
---------------	--------------------------------------	---------------

Scale	Sample Number....
	Weight.....
Polorimeter	Sample Number....
	Pol.....
Refractometer	Sample Number....
	Brix.....
	Temperature.....

Manual Sample Entry Screen:

Sample Analysis File		Date: 09/18/88
Enter New Records		
Plot Id: WHT-123-	1	Time: 1/50/58
1. Residue Weight..... 589.1 2. Observed Brix..... 15.4 3. Temperature..... 21 4. Polariscope Reading... 59.0		

Correct Sample Transaction Screen:

F7/END	
Daily Sample Transaction File	
Correct Records	
Plot Id: WHT-123-	1 Date: 09/18/88
1. Residue..... 523.4 2. Observed Brix..... 15.6 3. Temperature..... 21 4. Polariscope Reading..... 59.0 5. Variety..... cp99187 6. VCF..... 1.023 7. Number Stalks Per Test..... 15 8. Weight per Stalk..... 34.89 9. Juice Brix..... 15.67 10. Juice Sucrose..... 14.46 11. Juice Purity..... 92.29 12. TRS..... 218.12 13. Delete Record? Y on N.....	

Figure 6. Screens for transaction file maintenance.

### Pull Functions

In order to serve the various statistical analyses required by each researcher, programs (pull functions) were included to extract data from the crop-to-date or history file. By entering the 3-letter researcher code and starting and ending date, data were copied to a temporary file that was then backed up onto diskette(s). Also included were manual entry functions for the history file.

### CONCLUSIONS

This automation of analyses permits the processing of 300 or more samples of sugarcane per 8-hour day by three technicians. It also increases efficiency of technicians, minimizes the chance for error in observations and provides a data base for statistical analysis or further computations. Likewise, the whole procedure and computer software can be easily modified for commercial application in a cane payment system using the core sampler and press method to include weigh scale and laboratory analyses.

### ACKNOWLEDGMENTS

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# **HYDROSTATIC DRIVES FOR SUGARCANE MILLS: AN ALTERNATIVE TO TRADITIONAL STEAM POWERED DRIVES**

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## **ABSTRACT**

Traditional steam powered sugar mill drives, though robust in design, suffer from many deficiencies such as poor efficiency, intense maintenance and limited torque control. Hydrostatic drives, on the other hand, possess the necessary characteristics for a reliable sugar mill drive.

This paper will take the reader through the evolution of mill drives, discuss the operation and benefits of modern hydrostatic transmissions, and present a systematic approach for the successful application of hydrostatic drives on sugarcane grinding mills.

## **INTRODUCTION**

Up until the 1940's a steam engine driving a series of open gears was the most common type of mill drive. Today this type of mill drive is still used in some sugarcane factories but it is becoming increasingly rare.

From the 1940's to the present, a steam turbine driving through a series of open and/or enclosed gear sets has become widely accepted. The popularity of the steam turbine drive is due primarily to safety concerns and service aspects associated with the steam engine.

In spite of the steam turbine's popularity, a new type of mill drive is emerging which combines many features that have never before been claimed by any single drive package. As we approach the 1990's, worldwide attention is focusing on a new era in the evolution of mill drives - the hydrostatic drive.

Engineers in the sugar industry are beginning to recognize the advantages of using hydrostatic drives instead of the traditional thermo-mechanical drives. Technological advances of the last decade have enabled hydrostatic drives to surpass mechanical drives in many areas including operating flexibility, reliability, energy efficiency and component life. Energy savings will vary greatly depending on the type of thermo-mechanical drive currently being utilized and the type of hydrostatic drive being considered.

As the sugar industry continues to consolidate and modernize, the trend towards hydrostatically driven mills is undeniable. Today hydrostatic mill drives can be found operating successfully in countries around the world such as Mauritius, Indonesia, Cuba, India, U. S. A., Colombia and Pakistan.

The purpose of this paper is to familiarize the reader with:

- 1) Components and principles of operation of a hydrostatic drive.
- 2) Desirable characteristics of a sugar mill drive.
- 3) Advantages of a hydrostatically driven mill.
- 4) Different types of hydrostatic mill drive arrangements.
- 5) Guidelines for selecting a hydrostatic drive.

### **Components and principles of operation of a hydrostatic drive**

A typical hydrostatic drive consists of a prime mover, usually an electric motor, driving a positive displacement pump that transforms mechanical energy into hydraulic energy. The pump delivers this hydraulic energy to a positive displacement hydraulic motor via pipes and hoses.

The hydraulic motor then converts the hydraulic energy into mechanical energy, which is seen as shaft rotation.

The pump input shaft, driven by the prime mover, turns at a constant speed in one direction while the hydraulic motor output shaft is capable of infinitely variable speed in either direction.

The system operating pressure is determined by and is proportional to the load applied to the output shaft of the hydraulic motor while the direction and speed of the hydraulic motor output shaft is controlled by the direction and amount of oil flow coming from the pump.

Figure 1 (a) shows a simple, closed circuit hydrostatic drive with a variable volume pump driving a fixed volume motor. Internal leakage from the pump and motor cases is removed through case drain lines.

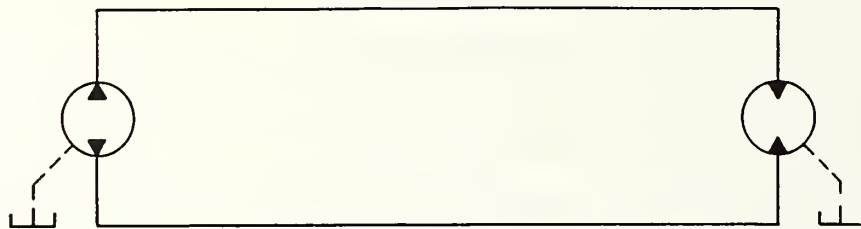


Figure 1 (a).

Usually the case drain from the pump is connected to the reservoir via a heat exchanger while the motor case drain is connected directly to the reservoir, Figure 1 (b).

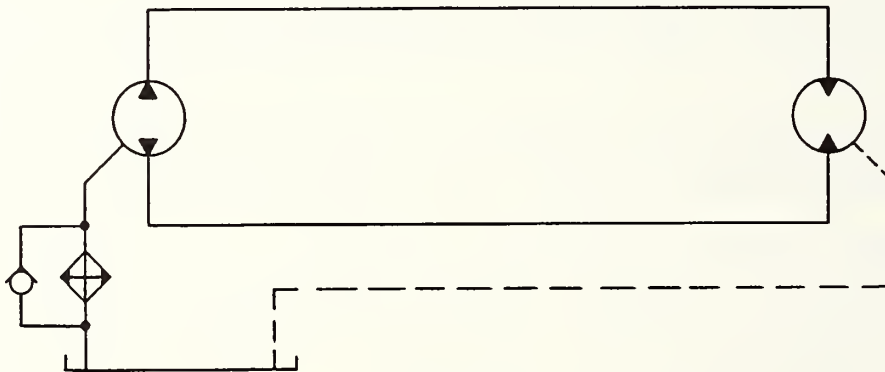


Figure 1 (b).

One of the most important items of a closed circuit hydrostatic drive is the charge pump, generally an integral part of the main pump, Figure 1 (c). The charge pump performs two functions: 1) it replenishes the closed circuit with fluid lost through the pump and motor case drains, plus 2) it replenishes the closed circuit with fluid removed via the shuttle valve, Figure 1 (d).



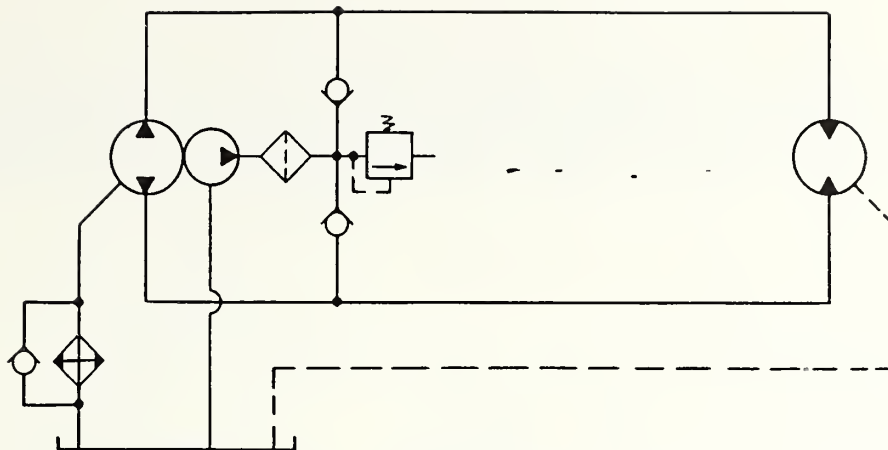


Figure 1 (c).

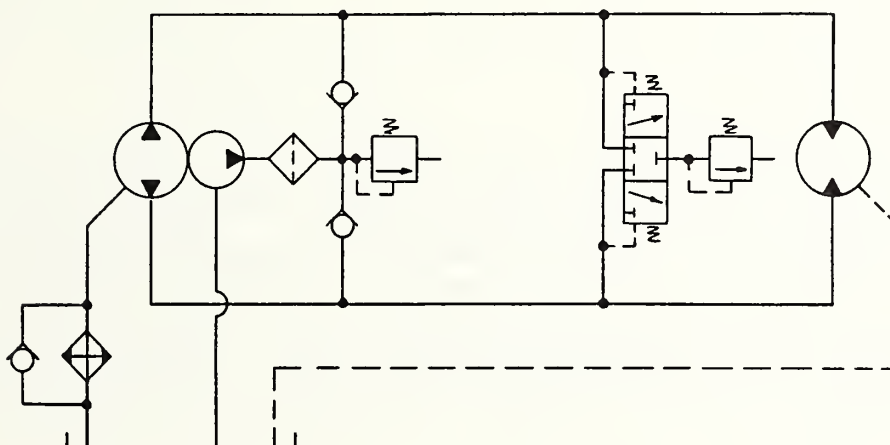


Figure 1 (d).

A typical closed circuit hydrostatic drive also requires crossover relief valves, which should be an integral part of the main pump, Figure 1 (e). Relief valves limit the pressure in either supply line due to shock load feedback through the motor.

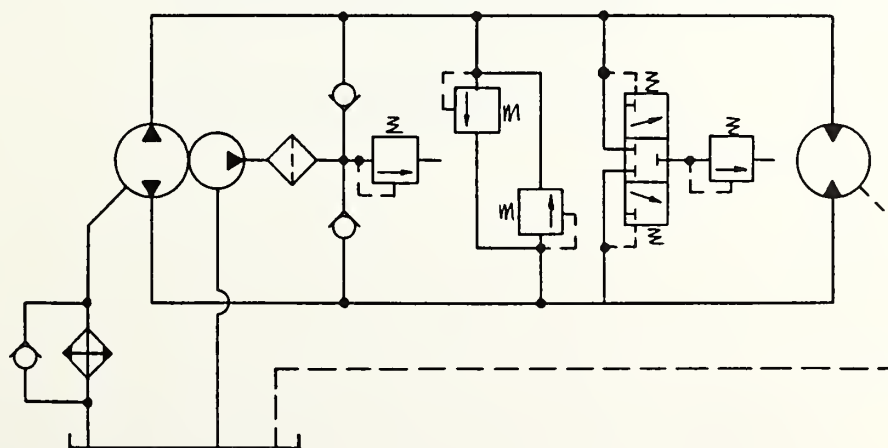


Figure 1 (e).

The term closed circuit describes how hydraulic lines in the main circuit are connected. Thus, in a closed circuit, the flow path is theoretically uninterrupted; in other words, the hydraulic fluid flows in a continuous, uninterrupted path from the pump discharge port to the hydraulic motor(s) inlet port and directly back to the pump. In an open circuit, the flow path of fluid is not continuous, being interrupted by the reservoir, Figure 2.



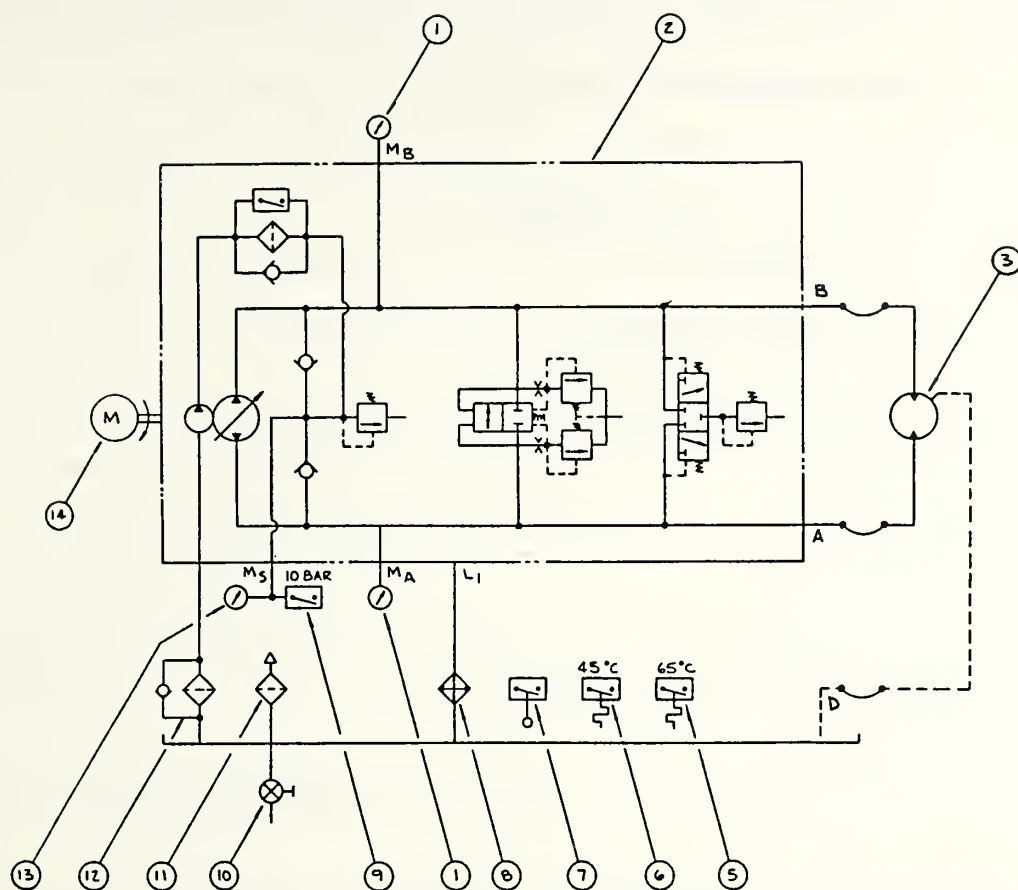
Figure 2.

The terms open loop and closed loop pertain to the existence of a feedback control signal from the motor to the pump. In an open loop there is no feedback signal to the pump and in a closed loop there is.

Due to the fact that very accurate speed control on a sugar mill is not usually necessary, most hydrostatically driven mills will have an open loop control system and a closed circuit hydraulic system.

Figure 3 shows a hydraulic system often employed with sugar mill drives. For this system, a fixed displacement hydraulic motor is selected based on speed and torque requirements, while the variable displacement pump is selected based on flow demands. Auxiliary components are selected for a multitude of functions which include:

- 1) Fluid conditioning circuit for proper temperature and cleanliness.
- 2) Inching drive for mill maintenance.
- 3) Torque limiting for mechanical and hydraulic component protection.
- 4) Control circuitry for exact mill speed and directional control.



14			1	ELECTRIC MOTOR
13			1	PRESSURE GAUGE
12			1	SUCTION STRAINER
11			1	RESERVOIR BREATHER
10			1	BALL VALVE
9			1	PRESSURE SWITCH
8			1	HEAT EXCHANGER
7			1	LIQUID LEVEL SWITCH
6			1	CARTRIDGE THERMOSTAT
5			1	CARTRIDGE THERMOSTAT
4				
3			1	HYDRAULIC MOTOR
2			1	AXIAL PISTON PUMP
1			2	PRESSURE GAUGE
DET	PART NO	MATERIAL	QTY	DESCRIPTION

Figure 3.

### Desirable characteristics of a sugar mill drive

Before one can fully appreciate and evaluate the advantages of a hydrostatically driven mill, the characteristics of an ideal mill drive system must be established. Some of these characteristics are:

- 1) Smooth, stepless speed control.
- 2) Good low speed capability.
- 3) Good starting performance under load.
- 4) High overall efficiency.
- 5) Low maintenance requirement.
- 6) Ability to reverse direction of rotation easily.
- 7) Insensitivity to ambient conditions.
- 8) High reliability.
- 9) Long service life.
- 10) Flexibility in design.
- 11) Availability of spare parts and service.
- 12) Inching ability.
- 13) Ability to automatically limit torque to prevent damage to the drive system during stall and overload conditions.

Based on the aforementioned design criteria, thermo-mechanical mill drive systems appear not to be the optimum solution. They require the drive components to be arranged in a fixed relationship where the location of the prime mover is not flexible. They are generally not easily or smoothly reversed nor do they possess stepless speed control throughout a wide speed range. They also tend to be large in size, heavy and require a lot of maintenance. Torque limiting is practically non-existent due to the very high rotating inertia present.

Electro-mechanical mill drive systems suffer from many of the same disadvantages associated with thermo-mechanical mill drive systems. Stepless speed control can be achieved but this requires a special, complicated control system for the electric motor.

Modern hydrostatic drives, on the other hand, possess all of the characteristics for a successful sugar mill drive system.

### Advantages of a hydrostatically driven mill

A properly designed, modern hydrostatic drive will possess all of the following advantages:

- 1) Easily achieved, stepless, variable, speed control from zero to maximum speed via a potentiometer or process signal while maintaining a constant speed (maximum efficiency) from the prime mover (electric motor or steam turbine).
- 2) Quick and easy reversing capability via lockable selector switch.
- 3) Very low rotating inertia and fast/accurate torque limiting means minimal damage to the mill, if any, because of mill jamming from tramp iron, stones, etc.



- 4) Design freedom - prime mover and pump can be placed in virtually any suitable/convenient location.
- 5) Extremely compact and simple to install with no alignment problems or concerns.
- 6) The ability to increase the mill capacity in the future with little or no modification to the drive system.
- 7) Very little maintenance is required other than changing filter elements when the indicator lights illuminate and having the oil analyzed periodically to determine when it should be changed.
- 8) With most hydrostatic drives, the mill can be started from zero rpm under full load. Therefore, the need to clean out the mill before starting is usually not necessary.
- 9) Hydrostatic drives are normally more efficient than a traditional thermo-mechanical drive, which means, less bagasse is used to produce steam and is available for other purposes such as making alcohol, paper, pressboard, electricity, etc.
- 10) With most hydrostatic drives there is the ability to inch the mill at very low speeds to perform maintenance on the rolls.

#### Different types of hydrostatic mill drive arrangements

Today there are basically three different types of hydrostatic mill drive arrangements available and in use (Figure 4):

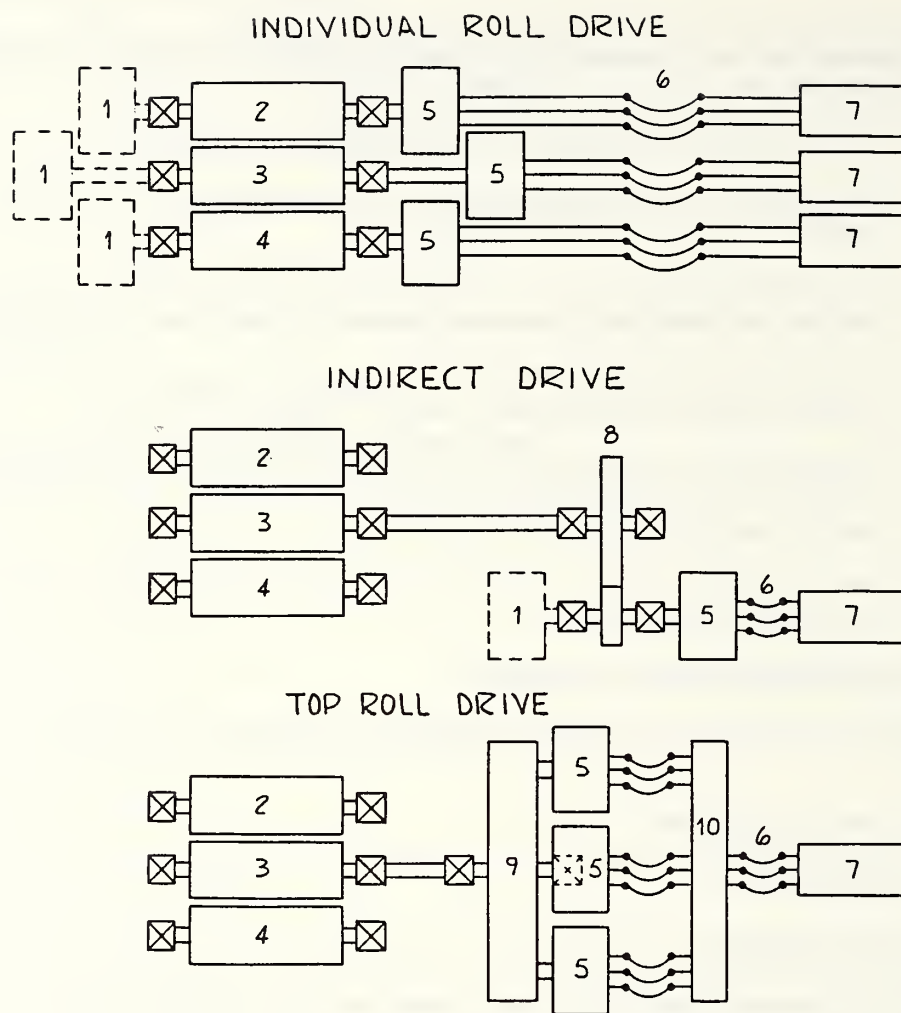
- 1) Individual roll drive.
- 2) Indirect drive.
- 3) Top roll drive.

Each drive arrangement has its own unique advantages and disadvantages which are outlined below.

Individual roll drive is the term used to describe a hydrostatic mill drive that has each of the mill rolls driven individually by one or two hydraulic motors depending on the size of mill.

The main advantage this arrangement has is the ability to vary the speed of the rolls in relation to each other. Reportedly the extraction rate can be increased slightly when the rolls are running at different speeds though this author does not make that claim. However, this drive arrangement has several disadvantages such as:

- 1) Each mill roll requires one or two hydraulic motors to be mounted onto new roll shafts connected to a minimum of one hydraulic pump per roll via a minimum of three pipes and hoses per motor, resulting in high installation costs.
- 2) Each time the mill requires services and the rolls have to be removed, the hydraulic hoses have to be disconnected from the motors and the motors have to be disconnected from the roll shafts. Thus, the integrity of the hydrostatic drive is in jeopardy each time the mill is serviced.
- 3) Because of the requirements for new roll shafts, plus the installation costs in terms of time and material, this type of drive arrangement is the most costly.



- |                               |                         |
|-------------------------------|-------------------------|
| 1 HYDRAULIC MOTOR-AS REQUIRED | 6 HOSES AND PIPING      |
| 2 FEED ROLL                   | 7 HYDRAULIC PUMP        |
| 3 TOP ROLL                    | 8 BULL AND PINION GEARS |
| 4 BAGASSE ROLL                | 9 ENCLOSED GEAR SET     |
| 5 HYDRAULIC MOTOR             | 10 MANIFOLD             |

Figure 4.

Indirect drive is the term used to describe a hydrostatic mill drive where the final open gear set is utilized and the pinion gear is driven by one or two hydraulic motors depending on the size of the mill. The main advantage here is cost savings, provided the bull gear (wheel) is in good condition and is capable of handling additional power requirements that may arise in the future. The only apparent disadvantage is the maintenance associated with the open gear set. However, if the bull gear and pinion are not in good condition, this type of drive arrangement becomes very costly and impractical.

Top roll drive is the term used to describe a hydrostatic mill drive where the final open gear set is removed and the top roll of the mill is driven by a hydraulic motor or hydraulic motor/gear reducer (torque multiplier) combination, depending on the size of the mill.

The main advantage with this drive arrangement is the ability to service the mill without disrupting the integrity of the hydrostatic drive.

In terms of cost, the top roll drive falls in between the individual roll drive and indirect drive but in terms of actual applications, the top roll drive is by far the most popular.

<u>Type of drive arrangement</u>	<u>Percentage of current worldwide applications</u>
Individual roll drive	18 %
Indirect drive	24 %
Top roll drive	58 %

#### Guidelines for selecting a hydrostatic drive

It is not uncommon for sugar factories to prepare detailed specifications covering the requirements of electrical or mechanical components and systems to be procured but seldom is there a detailed specification that outlines what is expected of hydraulic components and systems. This can prove to be very costly, especially if the hydraulic components or systems are large and the application in the factory is a critical one such as a mill drive.

Factory management should give careful consideration to having a detailed specification for hydrostatic drive systems prepared, similar to the ones used for electrical or mechanical systems. This specification will serve many purposes such as: being able to compare the various bid packages to get the one with the best value, being sure that all bidders have met specific company and industry standards, and ensuring that the ultimate supplier knows exactly what is to be expected before, during and after start-up.

The following is a recommended list of guidelines that need to be made clear to any potential supplier:

- 1) Pumps - There is only one type of hydraulic pump that should be used on modern hydrostatic drive systems - that is the axial piston, swashplate design pump in closed circuit. This type of pump is the most efficient and typically has the longest life expectancy of all pumps. Ideally this pump would be supplied with an integral charge pump, integral filters, integral relief valves and integral shuttle valve. By obtaining all these components as an integral part of the main pump, the chances for leaks are greatly diminished.
- 2) Motors - The radial piston, multi-cam lobe design is by far the best suited motor for sugar factory applications above 10,000 lb. ft. of torque. This type of motor is capable of very high output torques and very low speeds. The efficiency and life expectancy is unsurpassed by other types of motors.
- 3) Reservoirs - the reservoir should be sized for 2 1/2 - 3 times the size of the charge pump which should be 25% of the main pump flow. In other words, if the main pump flow is 200 gallons per minute, the charge pump should be capable of 50 gallons per minute and the reservoir should have the capacity to hold 125-150 gallons.
- 4) Heat exchanger - To ensure that the hydrostatic drive does not run hot, the heat exchanger should be capable of removing up to 20% of the installed power.

- 5) Operating pressures - Even though published technical data on hydraulic components state pressure of 4,500-6,000 psi, the properly sized hydrostatic mill drive should have a continuous operating pressure between 1,500-2,500 psi. Continuous operating pressures above 2,500 psi greatly decrease the component life as well as increase the noise level and chances for leaks, while pressures below 1,500 psi tend to create unnecessarily expensive drive systems.
- 6) Operating temperatures - Insist on a maximum oil temperature (measured in the reservoir) of 120° F. Operating temperatures above this level cause rapid deterioration in the oil quality and seals.
- 7) Leak prevention - The latest techniques should be employed to combat leaks. SAE 4 bolt flange or O-ring boss connections should be used wherever possible. The use of tapered pipe threads must be minimized and when used should be sealed using an anerobic type thread sealant.
- 8) Fluid conductors - Seamless tubing should be used as much as possible and the use of flexible hose should be kept to a minimum. The flow velocity in the main loop should not exceed 20 feet per second.
- 9) Industrial duty components - Component quality should match the application. If the application is heavy duty, demand heavy duty components made for the industrial market place not the mobile equipment market. Insist on supporting data to back up life calculations.

### CONCLUSIONS

Today's modern hydrostatic drive should not be compared with hydrostatic drives of the past. Tremendous advances in the last decade in the area of reliability, efficiency and leak prevention have enabled hydrostatic drives to be used successfully to power sugarcane grinding mills.

Whether an individual roll drive, indirect drive or top roll drive is utilized, the owner/operator should realize a vast improvement over a conventional thermo-mechanical drive system, provided the hydrostatic drive is properly designed, installed and maintained.



## AGRICULTURAL ABSTRACTS

### EFFECT OF SOIL AND PLANT EDAPHIC CONDITIONS ON SUGARCANE RUST IN FLORIDA

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Sugarcane (*Saccharum* spp.) production in Florida has been threatened by sugarcane rust (*Puccinia melanocephala* H. Syd. and P. Syd.) since 1978. Since this time, a number of commercial clones have shown increasing susceptibility to rust. In the Everglades Agricultural Area (EAA), casual observations have been made with respect to the effects of environmental and host factors on rust development. Specifically, two of these observations relate to what is referred to as the "rock road effect" and the apparent increased susceptibility of plant-cane over ratoon cane.

Past research has indicated significant relationships between plant nutrition and rust resistance, although the effects of the soil and plant conditions were not delineated. The objective of this study was to determine how rust disease infection is influenced and associated with soil and plant conditions. During 1988 and 1989, seven field locations that exhibited high variability in rust were selected. Rust intensity ratings and soil and plant leaf samples were taken at specific coordinate locations in each field. Results indicated that low soil pH and high soil test levels of phosphorus and potassium greatly enhanced the susceptibility of sugarcane to rust. Results also indicate that plant nutrient imbalances associated with soil conditions also contribute to disease susceptibility.

### EFFECTS OF FERTILIZERS AND SOIL PESTICIDES ON THE YIELD OF SUGARCANE

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An experiment was conducted with sugarcane on a Commerce silt loam soil to determine the effects of rates of fertilizers, carbofuran (Furadan®) and metalaxyl (Ridomil®) on the yield of fallow and succession planted cane. The fallow cane was planted in the traditional manner after a fallow year and the succession cane was planted on the same date immediately after harvesting a cane crop. For succession planting, the land was subsoiled after destroying the old cane stubbles with a roto-tiller. Rates of N, P and K fertilizers, metalaxyl and carbofuran applied in the fall at the planting time and in the spring were tested in plant, first, and second stubble cane.

Average results from the 3-crop years show that N-P<sub>2</sub>O<sub>5</sub>-K<sub>2</sub>O fertilizers at rates of 90-90-90 pounds/acre applied in the fall increased yield of succession cane, but rates above 120-0-80 applied in the spring of each crop year did not increase yields of fallow and succession cane. Carbofuran at a 10-pound/acre rate applied in the fall and spring of each year increased yields in fallow and succession cane. The yield increases from the fall-applied fertilizers were due to increases in stalk population without carbofuran and yield increases from carbofuran were due to increases in average stalk weight without fall fertilizers. Metalaxyl at a 1/2 pint/acre rate applied in the spring of each crop year did not increase yield of fallow and succession cane. The succession cane produced more yield with the fall- and spring-applied fertilizers than tradition fallow cane with only spring-applied fertilizer.

## AN OVERVIEW OF CYTOLOGICAL AND TISSUE CULTURE RESEARCH IN WILD AND CULTIVATED SUGARCANES

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The U. S. Department of Agriculture recently established a laboratory at the Sugarcane Research Unit for cytological and tissue culture research of sugarcane (*Saccharum* sp.). Worldwide, relatively few laboratories routinely conduct chromosomal research of sugarcane. Current objectives of cytological research are to determine chromosome number and metaphase I pairing in clones of wild sugarcane relatives, such as *S. spontaneum* L. *S. officinarum* L., and *Erianthus* sp., and commercial cultivars (interspecific hybrids) for clonal identification. In future work, chromosome pairing of interspecific and intergeneric hybrids will be studied to further our understanding of genetic mechanisms regulating chromosome pairing, to more efficiently incorporate desirable traits from wild species into commercial clones.

Current tissue culture studies include: 1) efficiency of plant regeneration from callus of true seed of sugarcane, and evaluation of progeny diversity, and 2) comparison of tiller and root proliferation in media containing either sucrose or corn syrup. An overview of data from cytological and tissue culture studies will be presented.

## FOOD CONSUMPTION OF DIFFERENT LARVAL INSTARS OF THE SUGARCANE GRUB, *LIGYRUS SUBTROPICUS* (COLEOPTERA: SCARABAEIDAE)

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The white grub, *Ligyris subtropicus*, Blatchley, is the most important grub species attacking Florida sugarcane. Feeding damage by *L. subtropicus* to the sugarcane plant is mainly larval feeding on the plant roots and underground stem. In this study, larval feeding rate of the three different larval instars of *L. subtropicus* were measured under simulated field temperatures. First and second instars consumed raw carrot at an average of 0.03 g/grub/week and 0.26 g/grub/week respectively. Third instars consumed raw carrot at varying rates during the nine months that the third instars naturally occur under field conditions. Mean monthly consumption of raw carrot by third instars ranged from 1.01 to 1.93 g/grub/week. Data in this study show that the appearance of *L. subtropicus* damage in September in Florida sugarcane fields is partially explained by increasing populations of the large and voracious third instars at this time. These data further emphasize the tremendous feeding capacity of each *L. subtropicus* third instar under field conditions found in Florida sugarcane fields. Lastly, these data emphasize the importance of correct timing of flooding for grub control to reduce sugarcane destruction by the voracious third instars.

## INFLUENCE OF THREE WATER REGIMES ON CHARACTERS OF INTEREST IN EARLY STAGES OF SELECTION

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Selection in Stage I of the Florida sugarcane breeding program is based solely on visual observation; no mill samples are taken. Characters such as small stalk diameter, cracks, pithiness (corn stalk type), and holes (tube) are selected against, although the effect of environment, particularly water, on the latter three characters and the relationship of these characters to yield is uncertain. The purpose of this experiment was to determine whether various soil water conditions affect expression of the characters under study and what effect pith and holes may have on yield. Twelve clones were selected which, in aggregate, expressed a range of phenotypes for diameter, cracks, pith, and holes. Single stools were planted into 10-gallon plastic cans and subjected to three treatments: dry, normal, and waterlogged. Each treatment had eight canes of each clone. Data were taken on stalk diameter, diameter of pith or hole, stalk weight, juice weight, and density. Results indicated that clones



differed significantly for density and extraction. Treatment effects were significant on stalk weight, juice weight, and extraction, but had nominal effect on expression of pith, holes, and cracks. Selection against these traits should be effective.

## **DISEASE INCIDENCE AND YIELD PERFORMANCE OF TISSUE CULTURE GENERATED SEEDCANE OVER THE CROP CYCLE IN LOUISIANA**

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Replicated field plot trials were established at nine farm locations in 1984 with variety CP 65-357 comparing three planting rates of tissue culture-produced seedcane (Kleentek) to a field run (control) source of seedcane planted at a 3-4 stalk rate. The planting rates for Kleentek were two stalks, three stalks, and 35 cm setts planted with a trash planter. Ratoon stunting disease (RSD) and sugarcane mosaic virus (SCMV) levels were monitored along with various yield components over the crop cycle, which included a plant cane, first and second ratoon at all locations, and a third ratoon at four of the locations.

RSD levels ranging from 25 to 100 percent were detected in control plots at four locations in plant cane while Kleentek at all locations and controls at five locations remained free of RSD through the second ratoon. Extremely high levels of SCMV were present in all controls (77 to 100 percent) throughout the study. Levels in the Kleentek material steadily advanced over the crop cycle with much variation occurring among locations. Over all locations, average SCMV levels in Kleentek for plant cane, first, and second ratoons were 10.7, 20.2, and 27.6 percent respectively.

Stalk production in the whole-stalk Kleentek treatments was significantly higher than control in plant cane and subsequent crops, while the sett planted treatment produced inconsistent results. No differences were detected between the two- and three-stalk planting rate for Kleentek. Sugar per ton (CRS) averaged 4.6 percent lower in the Kleentek treatments over all crops and locations. The combined analysis of these locations with RSD-infected controls revealed that whole stalk Kleentek treatments produced 25.5 percent higher cane tonnage and 19.2 percent more sugar per acre. At the RSD-free locations, the corresponding Kleentek yield advantages were 12.2 and five percent.

The overall margin of difference between Kleentek whole stalk treatments and controls widened with each successive crop, resulting in significant crop by treatment interactions. Among the four trials held for a third ratoon, sugar per acre increases with Kleentek ranged from 18.4 to 62.6 percent. Somoclonal propagation of healthy seedcanes does appear to be an effective system for combating systemic diseases impacting the Louisiana sugar industry.

## **PHENOTYPIC CHARACTERISTICS OF F<sub>2</sub> AND BC<sub>1</sub> PROGENIES FROM SUGARCANE INTERGENERIC CROSSES**

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Sugarcane-related genera have many desirable traits that can be used to improve sugarcane yield and adaptability. Genetic data on the economically important traits can serve as a guide to enhance germplasm utilization and to improve the efficiency of current breeding methodology. The objectives of this study were to examine the genetic behavior of some morphological and juice quality traits in the F<sub>2</sub> and BC<sub>1</sub> generations, and to estimate the level of attainment in the traits after first round gene recombination through backcrosses or self-pollination. F<sub>2</sub> and BC<sub>1</sub> seedlings from intergeneric crosses of sugarcane *Miscanthus* and sugarcane *Erianthus* were used and the characters evaluated were stalk diameter, fiber content, Brix, percent sucrose and percent purity. The results showed that the average sucrose content of F<sub>2</sub> and BC<sub>1</sub> progenies was markedly improved over that in the F<sub>1</sub> hybrids (F<sub>1</sub> vs F<sub>2</sub> and BC<sub>1</sub> are 4.78 percent vs 9.72 percent, respectively), but the average stalk diameter of those progenies was still very small (F<sub>1</sub> vs F<sub>2</sub> and BC<sub>1</sub> are 15.92 mm vs 14.59 mm). However, Brix and percent purity were improved nearly two-fold. The F<sub>2</sub> and BC<sub>1</sub> progenies gave a wide range of continuous variation in all five traits examined. The coefficients of variation indicate that the genetic variability

of F<sub>2</sub> and BC<sub>1</sub> progenies was slightly greater than F<sub>1</sub> clones. Juice quality of F<sub>2</sub> and BC<sub>1</sub> progenies was improved greatly, therefore selection for high juice quality should be effective in these populations. These results suggest that the improvement in stalk diameter may require additional backcrosses to reach an acceptable stalk diameter.

### SEED-CANE CROP AGE AND CLONE EFFECTS ON SUGARCANE PRODUCTION

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Sugarcane (a complex hybrid of *Saccharum* spp.) growers in Florida obtain seed cane primarily from plant cane rather than ratoon fields. Since plant-cane fields in Florida usually have the highest yields, the practice of using plant cane as a seed cane source was questioned. Also, ratoon yields are often reduced from plant-cane fields that have previously been used for seed cane. The objective of this study was to compare the productivity of seed cane of different crop ages, that is, from plant cane, first-, or second-ratoon fields. Four greenhouse and three field experiments were conducted during a 3-year period to determine levels of germination for the three crop ages. A total of 11 clones were tested in the seven experiments. For all experiments, plant-cane seed cane was obtained from fields planted in the previous January or February and all ratoon seed cane was obtained from fields that had been harvested in the previous March. In two of the four germination experiments conducted in the greenhouse, there were no germination differences because of crop age. In the other two greenhouse experiments, seed cane from first-ratoon fields had the highest germination. In three of the four greenhouse experiments, seed cane from at least one of the ratoon crops of clone CP 72-2086 had low germination. In the three field experiments, seed cane from ratoon fields produced tonnages at least equal to those produced by seed cane from plant-cane fields. Thus, in most cases, growers should consider that seed cane from ratoon fields will be at least as productive as seed cane from plant-cane fields. This could be an advantage for growers who prefer to use seed cane not contaminated with ratoon stunting disease (RSD) because they could use the same RSD-free source for more than one year.

### POTENTIAL IMPACT OF RATOON STUNTING DISEASE ON RECOMMENDED SUGARCANE VARIETIES IN LOUISIANA

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Seven sugarcane varieties are currently recommended for commercial planting in Louisiana. Evaluation of the effects of ratoon stunting disease (RSD) caused by *Clavibacter xyli* subsp. *Xyli* on these varieties began as each was selected for outfield testing. Disease-infected plants were compared to uninfected plants in each year of the 3-year crop cycle.

Recently released varieties, CP 79-318 and CP 76-331, have been evaluated over one and three crop cycles, respectively, while earlier released varieties, CP 74-383, CP 72-370, CP 72-356, CP 70-321, and CP 65-357, have been included in four to seven crop cycles. The greatest yield losses occurred in second ratoon crops. Over the crop cycle, the average loss of sugar from RSD exceeded 10 percent in each variety except CP 79-318 in which no detectable loss was observed. Increasing the planting rate of the RSD-infected sugarcane from approximately 1,175 1.8-m stalks per hectare to approximately 2,350 stalks per hectare did not affect the percent loss by RSD over the 3-year crop cycle.



## STAND REDUCTIONS CAUSED BY THE WIREWORM *MELANOTUS COMMUNIS* INFESTING PLANT CANE IN FLORIDA AND A YIELD-LOSS/WIREWORM-DENSITY RELATIONSHIP

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Stand reductions in plant cane caused by *Melanotus communis* were quantified in a series of tests conducted between 1982-1988. A standard measure of the number of wireworms/five row-feet (1.53 row-meters) was used. Seed pieces (variety CL 61-620) were planted at about 20 eyes/five row-feet in each test. Tests conducted between 1982-1986 employed 5-ft, singled row plots (20 replications), a 1987 test employed 10-ft, single row plots (20 replications), and a 1988 test employed plots two rows by 43.5 ft (four replications). The tests were conducted at sites where no wireworms were introduced at levels of from 0 to 12 wireworms/five row-feet along rows. Regression analyses of data from these tests indicated that stand reductions averaged 5.9 percent/wireworm/five row-feet during the first three months of cane growth ( $r = 0.95$ ). The stand loss/wireworm varied somewhat among individual tests, ranging from 4.6 percent up to 7.8 percent/wireworm five row-feet ( $r = 0.93$  to  $0.97$ ). In a 1988-1989 large-plot test, stand was reduced by 6.2 percent/wireworm/five row-feet ( $r = 0.97$ ) and final tonnage was reduced by 3.8 percent/wireworm/five row-feet ( $r = 0.92$ ). While stand and yield reductions caused by *M. communis* during a plant-cane crop may vary, data from these studies indicated that the wireworm is an important pest even when present at relatively low population levels.

## FLOWERING OF HYBRIDS FROM COMMERCIAL SUGARCANE BY *SACCHARUM SPONTANEUM* CROSSES

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The wild cane (*S. spontaneum*) is an important source of genetic variation in sugarcane breeding, but it is difficult to make interspecific crosses because many clones of this species flower earlier than commercial clones. Inheritance information on flowering time in interspecific crosses would be of greater benefit to the nobilization program. F<sub>1</sub> progenies of nine crosses of commercial clones by *S. spontaneum* were used to investigate the genetic behavior of flowering date and to estimate heritability. The F<sub>1</sub> hybrids were obtained from crosses of three commercial clones pollinated with stored pollen of three *S. spontaneum* clones. The F<sub>1</sub> progenies were planted in a randomized complete block design with four replications. Flowering data were collected on the first ratooning plants under natural field conditions. The results indicated that the F<sub>1</sub> progenies, on the average, flowered approximately 43 days later than their *S. spontaneum* paternal parents and approximately 67 days earlier than their commercial maternal parents. The frequency distribution of the flowering date of the F<sub>1</sub> progenies skewed toward late flowering date with a transgressive segregation that produced about four percent non-flowering clones. None of the F<sub>1</sub> hybrids flowered earlier than their *S. spontaneum* parents. The transmission of early flowering date from *S. spontaneum* to the F<sub>1</sub> progenies was very strong. The regression coefficient (b) of the F<sub>1</sub> progenies on midparent indicated that for each day of delay of the midparent flowering date, the average flowering date of the offsprings would be delayed by 0.83 days. The estimated broad sense heritability was very high with  $h^2 = 0.93$ . Therefore selection for flowering date would be effective. Since the majority of the F<sub>1</sub> progenies flowered earlier than the commercial clones, pollen storage and/or photoperiodic treatments are needed to overcome the difficulty of making backcrosses in the course of nobilization.

## REPEATABILITY OF SUGARCANE CLONE SMUT REACTIONS IN LOUISIANA

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Sugarcane clone disease reactions in smut spore dip inoculation tests were estimated to be moderately repeatable. In a resistance heritability study, estimates of smut reaction repeatability determined from variance components for parents and offspring between plant cane (PC) and first ratoon (FR) were 0.75 and 0.62, respectively, and 0.60 for parent clones in two PC crops. In smut inoculation tests conducted as part of the Louisiana State University cultivar selection program, repeatability estimates for experimental cultivars between

two PC tests were 0.41 in 1986 and 1987 and 0.52 in 1987 and 1988. Repeatability estimates for clones between PC and FR were 0.55 for 1986-1987 and 0.47 for 1987-1988. Estimates for clones rated as resistant, moderately susceptible, or highly susceptible in PC were 0.62, 0.14, and 0.43, respectively, between 1986 PC and 1987 FR and 0.28, 0.09, and 0.30, respectively, between 1987 PC and 1988 FR. Spearmans Rank correlation analysis indicated that smut resistance ratings assigned to experimental cultivars on a 1-9 scale were significantly correlated between crops and in different years. Correlation coefficients ranged from 0.33-0.65. The results indicate that genotype, environment, and the genotype x environment interaction significantly affect clone smut reactions in Louisiana, and multiple PC inoculation tests are needed to accurately assess smut susceptibility in experimental cultivars.

## **THE RELATION OF SUCROSE AND ASH CONTENTS AMONG SUGARCANE VARIETIES**

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In processing sugarcane, high ash content is known to lower sugar recovery. Sucrose and ash were determined in sugarcane juice expressed from 15 stalk samples during the 1988-89 harvest season in the Rio Grande Valley of Texas. The samples were taken from ten variety trials on two sampling dates (November and January). Four trials were plant cane with 12 test varieties, three were first ratoon with 15 test varieties and three were second ratoon with 14 test varieties. Two control varieties were common to all tests.

Analyses of variance showed, in addition to the anticipated significant differences in sucrose content, significant differences in juice ash content among varieties. Juice sucrose was negatively correlated with ash content in all individual tests on both sampling dates. Combining tests with common varieties gave stronger inverse correlations between ash and sucrose. A general correlation showed that ash decreased as sucrose increased ( $r = -0.5$ ,  $p = 0.0001$ ) and combined analyses showed that low-ash varieties, NCo 310 and CP 70-321, showed that the inverse relation between sucrose and ash existed among samples within a variety ( $r = 0.6$ ,  $p = 0.0001$ ), suggesting environmental as well as genetic influence. There were no apparent differences in these relationships among samples from different harvest dates or crop series.

## **CP 65-357 KLEENTEK TESTS IN LOUISIANA, 1985-1988**

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From 1985 to 1988, the effect of seed source on disease incidence and agronomic characteristics (including yield) of the variety CP 65-357 was studied. In these trials, progeny of CP 65-357 Kleentek (tissue culture produced seed cane which is a registered tradename of Crop Genetics International) was compared to progeny of hot water treated CP 65-357 and commercial field-run CP 65-357. The comparisons were made at outfield test locations representing all geographic regions of the Louisiana cane belt (small plots) and in a field scale test at Graugnard Farms in St. James, Louisiana (large plots). All tests were planted in a randomized block design with at least three replications and harvested through at least one complete crop cycle. Data collected over the four years indicated that CP 65-357 Kleentek yielded significantly more sugar per acre and tons of cane per acre than either RSD-infected CP 65-357 or progeny of hot water treated CP 65-357 in both outfield tests and in the field scale tests. Sugarcane mosaic virus and ratoon stunting disease incidence were generally lower in Kleentek material.



## **A REVIEW OF CHEMICAL RIPENING OF SUGARCANE WITH GLYPHOSATE IN LOUISIANA**

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Glyphosate (the isopropylamine salt of N-phosphonomethyl glycine) is recommended as a foliar spray to stimulate the early ripening of sugarcane (*Saccharum* interspecific hybrids). Glyphosate increases yield of sugar/hectare by increasing sucrose content and, in some instances, reducing the fiber content of harvested cane. Further, the use of glyphosate causes some leaf desiccation resulting in improved field burn. The efficacy of glyphosate is influenced by variety, cane tonnage, health of cane, treatment-harvest interval, and the climatic conditions at the time of and immediately following its application. Surfactants have not been shown to enhance efficacy. Drift and/or application of glyphosate to seed cane or non-targeted fields may result in poor germination or reductions in tonnage yields. Glyphosate does not appear to pose any deleterious effect on the subsequent stubble crop when applied at the recommended rate and the crop is harvested within the proper treatment-harvest interval.

## **THE EFFECT OF PLANTING DATE ON TIME OF INITIATION OF 16 SUGARCANE CULTIVARS**

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Sixteen sugarcane cultivars were planted at three dates (September 6, 1986, November 17, 1986, and January 29, 1987) with two reps at each date. Meristems were harvested eight times at 1-week intervals starting on September 2, 1987 and ending on November 5, 1987. Immediately after harvest, the meristems were dissected down until they were approximately 1 cm in diameter and 4-5 cm in length. They were then placed in FAA, where they remained until the meristems were sliced and measured under binocular microscope in the summer of 1988.

Initiation was found on October 8, 1987 in CP 70-1527, CP 72-1210, CP 72-2086, CP 74-2005, CP 75-1082, CP 78-1610, CP 80-1743, CP 80-1827, CP 81-1302, and CP 81-1383. The remainder of the cultivars, CP 70-1133, CP 77-1776, CP 78-1247, CP 78-2114, CP 80-1557, and CP 81-1254, first showed signs of initiation on October 22, 1987. On average, the percentage of stalks that initiated, after initiation was first detected, were 44, 51, and 35 percent for the September, November and January planting dates, respectively. However, the frequency of stalks initiated varied among clones within planting dates and among planting dates within clones. The September planting ranged in percentage of initiated stalk from a low of 15.6 percent for CP 81-1254 to a high of 65.65 percent for CP 70-1133. The November planting date ranged in percentage of initiated stalks from a low of 18.8 percent for CP 80-1827 to a high of 87.5 percent for CP 78-2114. In the January planting date, the lowest frequency of initiation was in CP 80-1557 with no initiation to a high of 83.3 percent for CP 70-1527.

## **PARTICULATE AIR QUALITY IN A SUGARCANE AGRICULTURAL AREA**

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The Florida Sugar Cane League (FSCL) monitors total suspended particulate (TSP) and PM10 particulate (less than 10 micrometers in diameter) in the Everglades Agricultural Area (EAA) and surrounding communities. Collected data have been analyzed to determine: 1) if seasonal TSP fluctuations associated with sugarcane harvesting operations exist, 2) if there is a corresponding PM10 fluctuation, and 3) the relationship of particulate air quality in the EAA with other areas in Florida and the U. S. Results indicate that while a seasonal fluctuation does occur in TSP levels, the corresponding PM10 fluctuation is much less pronounced. EAA TSP levels appear to be comparable to urban areas in Florida and considerably less than levels in many metropolitan areas in the U. S.

## ENTOMOGENOUS NEMATODES AS BIOLOGICAL CONTROL ORGANISMS OF SUGARCANE PESTS

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Integrated pest management involves the utilization of various control approaches to minimize losses caused by insect pests. In Florida, sugarcane pests are mainly controlled with pesticides. Pesticides are needed, but an overdependency on this control method can be detrimental to the ecosystem. The development of resistance to pesticides by insect populations and the adverse effects of pesticides on beneficial insects and the environment are well documented. Nematodes are actively being investigated by scientists as biological control agents. This is reflected in the volume of papers being published on this subject. Recent advances in rearing and packaging of these organisms are making prospects of their use more plausible.

Laboratory tests have shown that nematodes kill sugarcane borer larvae inside infested stalks. When various concentrations of the nematode species *Steinernema feltia* Filipjev, and *Heterorhabditis heliothidis* (Khan, Brooks, and Hirschman) were tested, 100 percent mortality of sugarcane borer, *Diatraea saccharalis*, larvae was observed when treated with 5,000 nematodes per larva. Only 30 percent mortality was observed with *Steinernema glaseri* (Steiner). However, *S. glaseri* is the most effective (100 percent against the white grub, *Ligyrus subtrropicus* (Blatchley). In small field tests, half of the white grubs collected from the treated area were infected with *S. glaseri* nematodes. Several nematode species have been tried against wireworms without success. It is suggested that the potential of nematodes as biological control agents of pests of sugarcane be investigated.

## SUGARCANE YIELDS AS INFLUENCED BY RESIDUAL AND FERTILIZER N

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Two studies were conducted to determine the N and P fertilizer requirements of an early-season sugarcane cultivar CP 70-321 on Rynosa silty clay loam (*Fluventic Ustriochnips*). Nitrogen as urea was applied at rates of 0, 90, 180, 270 and 360 kg/ha and phosphorus (P) as treble superphosphate at rates of 0 and 100 kg P<sub>2</sub>O<sub>5</sub>/ha. A randomized split-plot design with four replications was used. With the first ratoon crop all the P and half the N was placed in a band 10 cm below the soil surface on each side of the cane row in February 1984. The remainder of the N was broadcast over the cane row in April. In order to study the residual effects of the various fertilizer rates, the previous year plots were split with half the plot area of the second ratoon crop being fertilized with N and P.

All fertilizer was banded in April 1985. Throughout the growing season of both crops, leaf blades and sheaths numbered three through six were collected from five stalks in each plot. The tissue samples were dried at 70° C for moisture determination and analyzed for N, P, K, Ca and Mg. The first ratoon crop received 100 cm of water in nine irrigations and 38 cm of rainfall. Corresponding values for the second ratoon crop were 89 cm in eight irrigations and 58 cm of rainfall. Following burning of the study area in December 1984 and January 1986, the cane was hand harvested from 46m<sup>2</sup> of each plot and weighed. Fifteen stalks were randomly removed for milling and analysis.

Nitrogen significantly increased yields over the non-fertilized yields in each year of application. The magnitude of the yield response varied between years and was dependent upon the quantity of N applied to previous crops. The non-fertilized first ratoon produced 78 percent of maximum yield (72.4 Mg/ha), which is indicative of considerable available N, while the non-fertilized second ratoon produced 49 percent of maximum yield (47.2 Mg/ha). Yield increase of 3.0, 9.8, and 10.9 Mg/ha were attributed to residual N from 180, 270, and 360 kg N/ha applications to the first ratoon crop. Yield differences between the first and second ratoon crops



may reflect the depletion of soil-derived N. Non-fertilized cane yields decreased by 34.7 percent between the first and second ratoon crops. Corresponding yield decreases were 28.9, 13.4, 10.5, and 8.2 percent for cane fertilized with 90, 180, 270 and 360 kg N/ha.

In both years, the tonnage production curves suggested that 190 kg N/ha was required for maximum yields. Juice quality and sugar content were depressed with increasing amounts of N. Tissue analysis revealed that excess N encouraged high leaf N percentage and high sheaths moisture percentage, both of which contributed to keeping the sugarcane vegetative late in the season. The cane did not respond to the application of P.

#### **RESISTANCE MECHANISMS OF SUGARCANE CULTIVARS TO THE YELLOW SUGARCANE APHID**

William H. White  
USDA-ARS Sugarcane Research Unit  
Houma, Louisiana

Because of heavier than normal infestations of the yellow sugarcane aphid (YSA), *Sipha flava* Forbes, during 1985 and 1986 growing seasons, increased attention has been given to this insect by Louisiana sugarcane scientists, crop consultants, and growers. Although long associated with sugarcane in Louisiana, little is known about YSA in the Louisiana sugarcane agroecosystem. Recent YSA outbreaks appear to be related to early and repeated applications of Fenvalerate (pydrin). However, environmental conditions and cultivar susceptibility, undoubtedly contributed to recent outbreaks of YSA. The role of preference and antibiosis in resistance to YSA was studied in the following six Louisiana sugarcane cultivars: CP 65-357, CP 70-321, CP 72-356, CP 72-370, CP 74-383, and CP 76-331.

Preference studies revealed that CP 72-370 and CP 72-356 were more preferred, while CP 70-321 was least preferred. The degree of antibiosis, measured in days reproduction, total nymphs produced, and number of nymphs produced per day, was the least in CP 72-356 and CP 76-331. The cultivars CP 65-357 and CP 70-370 expressed the highest levels of antibiosis.

## **MANUFACTURING ABSTRACTS**

### **THE OPERATION OF TWO 4-ROLLER MILLS AT ATLANTIC SUGAR ASSOCIATION**

Jose' F. Alvarez, Adalberto Pacheco, and Hector J. Cardentey  
Atlantic Sugar Association, Belle Gloade, Florida

For the crop of 1987-1988, Atlantic Sugar modified the last mill on a 7-mill tandem to accommodate a forced feed roller, thereby converting the conventional 3-roll mill into a 4-roll mill.

The sixth mill of the tandem was converted into a 4-roller mill for the 1988-1989 crop. A comparison of the two crops is made, emphasizing the advantages of two 4-roller mills, working as the last two mills of a tandem. Also, the operation of the 4-roller mill is discussed as related to the crop of 1988-1989.

### **FACTORS AFFECTING PROFITABILITY OF RAW SUGAR FACTORIES IN LOUISIANA**

Brian A. Chapman, Research Associate and  
Ralph D. Christy, Associate Professor  
Agricultural Economics and Agribusiness Department  
LSU Agricultural Center  
Baton Rouge, Louisiana

Prior to 1982, the Louisiana sugarcane processing industry was becoming increasingly concentrated as the number of raw sugar factories declined, while average factory size increased. Since 1982, the number of processors has remained constant (21 processors), yet average factory size has continued to increase. The current distribution of processors within the Louisiana cane belt is such that the failure and removal of specific factories could dramatically impact sugarcane transportation costs, and perhaps result in some sugarcane acreage being diverted to uses other than the production of sugarcane. Cost, income, and physical data from 19 Louisiana raw sugar factories for nine grinding seasons (1979-87) were analyzed to determine the impact of selected factors (e.g., size, crs, firm organization) on the profitability of these firms.

### **ANTISCALANT PERFORMANCE IN PILOT SCALE EVAPORATORS**

Stephen J. Clarke, Audubon Sugar Institute  
Louisiana Agricultural Experiment Station  
LSU Agricultural Center, Baton Rouge, Louisiana

Two pilot evaporators were constructed and operated on mill-clarified juice at Raceland factory during the 1988 crop. The first unit contained four removable tubes that were weighed after each run; the second unit had flat detachable plates, of different metals, if desirable, so that the scale could be examined without damage. Both were operated at atmospheric pressure, to parallel the first effect of the factory quadruple effect, and with the same schedule as the factory evaporator. Results with varying antiscalants will be presented.

## **STATISTICAL EVALUATION OF BOILING HOUSE ANALYTICAL DATA**

Stephen J. Clarke, Audubon Sugar Institute  
Louisiana Agricultural Experiment Station  
LSU Agricultural Center, Baton Rouge, Louisiana

One factory laboratory in Louisiana keeps meticulous data on all strikes during the crop, including the pan number and the identities of the pan boilers and analysts. A statistical analysis of all this data has been performed to study trends in massecuite and molasses purities and to compare the results achieved with varying vacuum pans and by the different personnel. The value of such data and results of the comparisons will be discussed.

## **OPERATING IMPROVEMENTS AT FLORIDA CRYSTALS REFINERY**

Gerardo F. Fundora and Roberto Comacho  
Zanini International  
Miami and Brazil, Coconut Grove, Florida

Saving on steam used by the vacuum pans and shortening the strike boiling time was achieved by increasing the capacity of the evaporation unit because of higher concentration on the liquor fed to vacuum pans. Vacuum pan mechanical circulator drives were upgraded to finish the strike at a higher concentration, yielding more sugar and run-off with lower purity. Purging time was substantially reduced by increasing the centrifugal's basket from 48 by 30 to 48 by 36 inches.

## **IMPROVEMENT OF LOW GRADE EXHAUSTION AT ST. JAMES SUGAR COOPERATIVE, INC.**

Manolo A. Garcia  
St. James Sugar Cooperative, Inc.  
St. James, Louisiana

A study made in the 1987 crop of the low grade station at St. James Sugar Cooperative, Inc. showed that dilution of the C massecuite to enhance flow in the series of horizontal crystallizers has detrimental effects on the final molasses purity. Changes were made to do away with the dilution and still allow for normal processing of the low grade for the 1988 crop. Results at the end of the crop showed a significant improvement of two points additional purity drop in the final molasses.

## **REDUCING WEAR OF SUGARCANE PROCESSING EQUIPMENT COMPONENTS UTILIZING HIGH TECHNOLOGY THERMAL SPRAYED COATINGS**

Robert A. Hipkind  
Vice President, Market Development  
C<sup>3</sup> Technologies, Inc., Chicago, Illinois

This paper deals with solutions to the problem of deterioration of mechanical components used in the processing of sugarcane. An analysis is made of the wear mechanisms and commonly used materials that are unable to combat wear in current sugar mill operations. A parallel is drawn with other industries that have solved similar problems by employing state-of-the-art, high-technology thermal sprayed coatings. A review is made of specific machine components processing sugarcane that have been or are seen to be coated. Finally, an estimate is made of anticipated service life increase and the total savings that are accrued, including maintenance and replacement costs, as well as production and quality issues that affect the bottom line.



## COMPARISON OF CLARIFICATION REAGENTS FOR POLARIZATION ANALYSIS OF SUGARCANE JUICE

B. L. Legende

USDA-ARS Sugarcane Research Unit, Houma, Louisiana

Margaret A. Clarke

Sugar Processing Research, Inc., New Orleans, Louisiana

Lead subacetate has been the reagent of choice for clarification for polarization analysis of cane juices and sugars. The lead reagent precipitates suspended solids and de-colorizes the juice sample, resulting in a clear, light-colored filtrate that is required for a satisfactory polarimeter (pol) reading. Under the EPA Hazardous Waste Law, the Resource Conservation and Recovery Act (RCRA) of 1984, the disposal of heavy metals in landfills after 1990 will be unlawful, dramatically increasing the cost of lead subacetate disposal. An alternative reagent, aluminum chloride, was compared with lead subacetate as a clarification reagent for polarization analysis of sugarcane juice. The objectives of this study were to determine if (1) the alternative reagent will clarify sugarcane juices, and (2) the two procedures give similar polarization results. A paired comparison of 1,085 juice samples showed that aluminum chloride, in combination with calcium hydroxide, will clarify fresh and partially deteriorated sugarcane juices, including juices from cane samples taken 18 days following a moderate freeze ( $-3.3^{\circ}\text{C}$ ). However, the filtration time using aluminum chloride reagent averaged 9.3 minutes/100 ml filtrate as compared with 3.7 minutes/100 ml filtrate using lead subacetate.

The pol readings from the two analyses showed a near perfect, linear relationship ( $R^2 = 1.00$ ). Consequently, to convert pol determined using aluminum chloride to pol determined using lead subacetate, use the following formula:

$$\text{Pol by lead subacetate} = \\ (.0113 \times \text{Pol by aluminum chloride}) - 0.3346$$

Aluminum chloride can be used as a substitute for lead subacetate in polarimetric analysis without loss of precision, reliability, or increase in cost; however, time to prepare and process samples is increased.

## DEXTRAN ANALYSIS - A COMPARISON OF METHODS

D. Sarkar, D. F. Day, S. J. Clarke, and M. Saska

Audubon Sugar Institute

Louisiana Agricultural Experiment Station

LSU Agricultural Center, Baton Rouge, Louisiana

Commercial sugar producers are assessed yearly penalties in the millions of dollars for excessive levels of dextran in commercial raw sugars. Questions have been raised as to the specificity and reliability of the accepted commercial analytical method, the Haze Text. We undertook to compare this method with an enzymatic analysis procedure, two antibody procedures and a gel chromatography method. An evaluation of these techniques as to their suitability and reliability will be presented.

## ION-EXCLUSION IN THE SUGARCANE INDUSTRY

Michael Saska, Audubon Sugar Institute

Louisiana Agricultural Experiment Station

LSU Agricultural Center, Baton Rouge, Louisiana

A review is presented of the state of development of large-scale ion-exclusion separation. Several options, including a post-season desugarization of low-purity sugarcane solutions, are discussed for potential future applications in the sugarcane industry.



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### Nature of papers to be published:

Papers submitted must represent a significant technological or scientific contribution. Papers will be limited to the production and processing of sugarcane, or to subjects logically related. Authors may submit papers that represent a review, a new approach to field or factory problems, or new knowledge gained through experimentation. Papers promoting machinery or commercial products will not be acceptable.

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# **RULES FOR PREPARING PAPERS TO BE PRINTED IN THE JOURNAL OF THE AMERICAN SOCIETY OF SUGAR CANE TECHNOLOGISTS**

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Unless the nature of the manuscript prevents, it should include the following sections in the order listed: ABSTRACT, INTRODUCTION, MATERIALS and METHODS, RESULTS, DISCUSSION, CONCLUSIONS, ACKNOWLEDGMENTS, and REFERENCES. Not all the sections listed above will be included in each paper, but each section should have an appropriate heading that is centered on the page with all letters capitalized.

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## **Suggested Format (Examples below)**

### **EVALUATION OF SUGARCANE CHARACTERISTICS FOR MECHANICAL HARVESTING IN FLORIDA**

**J. E. Clayton and B. R. Eiland  
Agricultural Engineers, SEA, USDA, Belle Glade, Florida**

**J. D. Miller and P. Tai  
Research Geneticists, SEA, USDA, and Canal Point, Florida**

**ABSTRACT**

**INTRODUCTION**

**MATERIALS AND METHODS**

**RESULTS**

Table 1. Varietal characteristics of nine varieties of sugarcane over three-year period at Belle Glade, Florida.

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Figure 1. Relative size of membrane pores.

#### DISCUSSION

#### CONCLUSIONS

#### ACKNOWLEDGMENTS

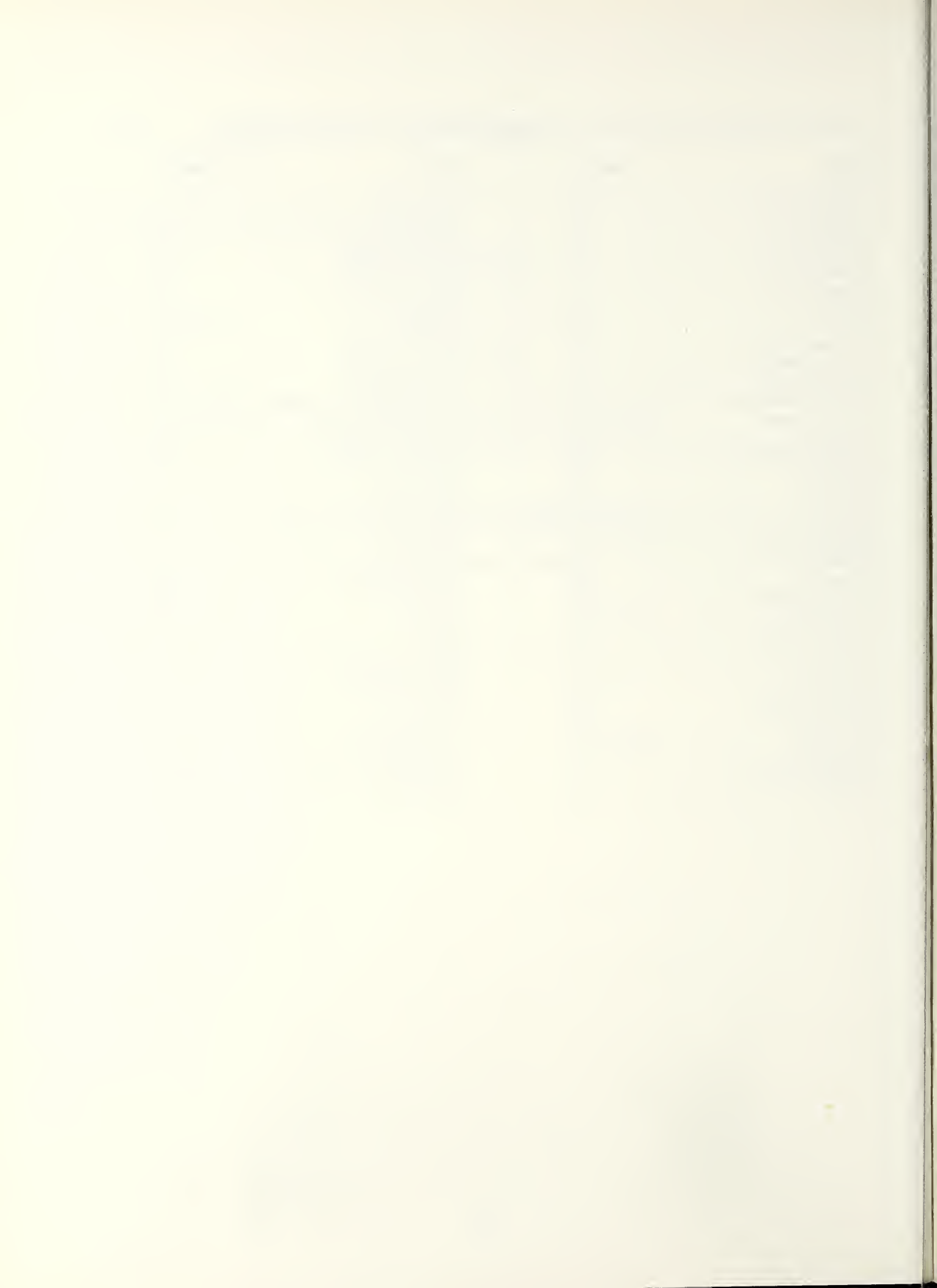
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## **PRESIDENT'S MESSAGE FLORIDA DIVISION**

**Ron DeStefano**

I am very pleased to welcome fellow members of the Florida Division, our friends from the Louisiana Division, and guests to the 20th annual joint meeting of the American Society of Sugarcane Technologists.

The 1989-90 crop in Florida provided some striking contrasts to last year's record crop. Unlike the Louisiana industry, Florida did not set any new production records this year. Though Florida farmers grew 413,000 acres of cane, just 13,435,065 tons of cane reached the seven Florida mills this year. This was about 150,000 tons less than last year's crop, which was grown on just 408,000 acres. Total sugar production fell to 1,399,332 short tons, raw value, a drop of over 160,000 tons from last year's record. Final overall yield was 10.23 percent, down over a full point from last crop's 11.32 percent. Mother Nature was not as kind to us this year as she was last. Severe freezes on December 24th and December 25th caused widespread damage throughout the Everglades Agricultural Area. Low temperatures of 23°F were recorded both nights, and the temperature remained below freezing for 11 hours on the 24th and for 13-1/2 hours on the 25th. In very short order, the South Florida landscape turned a uniform brown color and the crop began to deteriorate. The excellent early-season yields began to drop along with juice purities. Though some viable seedcane was eventually located, the planting of the new crop was severely impaired as well. The new crop now looks very good, but continuing drought poses a danger for the immediate future.

On the bright side, sugar prices remained strong during the year, as consumption worldwide outstripped production for the fifth straight year. Several quota adjustments, made necessary by lower-than-expected production in all areas of the U.S. industry except Louisiana, coupled with failure of foreign quota holders to ship sugar on schedule resulted in a 2.6 million metric ton quota for 1989-90. Since the 1985 Farm Bill was enacted the sugar program has worked as intended, preserving a viable and efficient U.S. industry, ensuring a reliable supply of sugar at a stable price for consumers, and providing markets to our traditional trading partners.

The consumption of sucrose is also slowly increasing in the U. S. The explosive growth of high fructose corn syrups seems to have levelled off, and the good news about sucrose seems to be getting out to the public. A 1988 FDA Task Force concluded that "Other than the contribution to dental caries, there is no conclusive evidence that demonstrates a hazard to the general public when sugars are consumed at the levels that are now current and in the manner now practiced." The Sugar Association, which represents all of us, has taken on the very important job of spreading this news to the public via advertising and educational programs.

Nutrition research indicates that the fad diets, popular in the 70s and 80s do not work; that lost weight is usually "found" again. Current recommendations include exercise, a healthy diet, and moderation to keep off excess weight. Recent studies indicate that artificial sweeteners, so eagerly embraced by dieters, may be ineffective as weight loss aids; they simply cause calories not eaten as nutritive sweeteners to be replaced by calories from other sources such as increased fat consumption. Sugar has been found to be a useful part of a healthy diet. A small portion of dessert after a meal has been found to be effective in warding off the feeling of deprivation that causes so many well-intentioned dieters to binge on fat and sugar-rich food.

Nutritionists also tell us that the American diet contains too much fat, and a new synthetic fat substitute made from sucrose derivatives may be a partial solution to this problem. The Proctor & Gable Company has produced a sucrose polyester formulation that looks, cooks, and tastes like fat but is not metabolized by the body and thus does not contribute any calories to the diet.

Synthetic fats are just one example of the new products that may be made from sucrose in the future. The Sugar Association is also active in the field of sucrochemistry and has funded several studies on novel new uses for sucrose. Dr. Charles Baker of the Sugar Association will report on some of these efforts later in our program.

The environment continues to be a prime concern in South Florida. In combination with the Florida Sugar Cane League's extensive activities in the area of air and water quality monitoring, growers and in the Everglades Agricultural Area created in the Everglades Agricultural Area Environmental Protection District. Creation of the District will allow agriculture to take a leading role in solving the complex problems of the Everglades, while providing for the water needs of agriculture and a burgeoning urban population. In the District's first year, area farmers were assessed \$5.00 per acre and raised over \$2.5 million for environmental protection projects. Active efforts include assistance for the construction of deep-well injection projects to eliminate phosphorus presently entering Lake Okeechobee from three city sewage plants, \$500,000 for a nutrient-removal area for water entering the conservation area and Everglades National Park, and a grant to the Duke University Wetlands Center for a five-year study of methods to improve management of the water conservation areas so as to protect the unique Everglades ecosystem, preserve our water supply, and provide flood protection.

While we toil in the field, the factory, or the laboratory to more efficiently produce cane, sugar, and sugar byproducts, our representatives in Washington work just as hard to be sure our voice is heard on matters relating to our livelihood and to the welfare of the domestic sugar industry in general. At the top of their agenda now is the 1990 Farm Bill. This process really began several years ago when industry representatives were asked by Congressional leadership to meet in order to formulate ideas for the 1990 Sugar Title. In early May, the House Agriculture Subcommittee on Cotton, Rice and Sugar reported a proposed five-year bill that includes both sugar and corn sweeteners in a no-cost loan program similar to what we have had. The cornerstone of the sugar title has been the "no-cost" provision, which now requires a minimum quota in order to guarantee its preservation and is also beneficial to friendly foreign trading partners. The simple facts are that the sugar industry must be united behind these and other provisions in order to pass a Sugar Title just as all affected agriculture must be united in order to pass a Farm Bill.

Some differences do exist from the previous Sugar Title, but we are optimistic that the bill finally passed by Congress will be acceptable to U.S. sugar producers and will carry out the will of the American public as expressed in a recent national opinion poll. Fully 75 percent of the public feel that the no-cost U.S. program should be continued as long as foreign governments subsidize and protect their own sugar industries. We fully expect the program to continue to assure the U.S. a plentiful supply of sugar at a stable price, allowing the continued survival of an efficient U.S. industry providing jobs to many thousands of Americans, as well as providing continued access to the U.S. market for our traditional trading partners.

Let me close by saying that the people in this organization constitute the sugar industry's best chance for long-term survival. It is you who will make the industry the most efficient and the most technologically advanced in the world. It is our hope that everyone here takes home something that may further this goal and that each of you experiences a most productive 20th joint meeting.



**PRESIDENT'S MESSAGE  
LOUISIANA DIVISION**

Martin Cancienne

The advent of the new decade has brought with it many challenges to our industry, including the adoption of a new multi-year omnibus farm bill and the uncertainty surrounding the status of the 1990 crop.

The 1989 sugarcane crop culminated with what might come to be known as the three best consecutive years (1987-89) ever experienced by the Louisiana sugarcane industry. Sugarcane for sugar and seed totaled 8,329,000 tons, up better than six percent from 1988. Acres harvested were 315,000--10,000 more than last year. Yield per acre was estimated at 26 tons compared to 25.3 in 1988. The crop remained in good to excellent condition throughout the year. Borers were a problem for a time during the summer when rain was abundant. The state averaged 203 pounds of sugar per ton of cane. This yield resulted in more than 845,000 tons of sugar for the state. This is the largest quantity of sugar ever produced and is some four percent higher than last year's record production. This record may not be challenged for several years as a result of a natural phenomenon that occurred at the end of grinding season.

Friday, December 22, 1989, was the beginning of the coldest arctic blast ever experienced in the state of Louisiana. By the time the cold had subsided, South Louisiana had recorded a record 80 hours of continuous sub-freezing temperatures (previous record: 1983 - 59 hours). The USDA Sugarcane Field Laboratory in Houma, Louisiana, registered a record low temperature of 8.9°F. This recording surpassed the previous record low temperature of 13.5°F set during the Christmas freeze of 1983. As a result of the freeze experienced in late 1983, the subsequent sugarcane crop (1984) production was reduced by over 25 percent. Given the longer duration and colder temperatures experienced by the recent freeze, compared to 1983, the potential for as much or even a greater loss in production for this crop year is apparent.

If the outcome in loss of production with the 1984 crop is any indication of what to expect in 1990 as a result of a natural disaster of greater magnitude, the sugarcane industry may suffer a potentially serious economic setback. Preliminary estimates indicate yield losses could run as high as 60 to 70 percent in some areas. I think I can safely say that this freeze may prove to be the worst disaster to hit Louisiana sugarcane since disease nearly wiped out the industry in the 1920s.

The Food Security Act of 1985 is scheduled to expire in 1990. In order to re-authorize or modify the programs included in this legislation, Congress must approve and the President must sign a 1990 farm bill. Agricultural price and income support programs are key features of the law, which also includes provisions regarding conservation, commodity supply control, agricultural trade, research, credit, food stamps, and various other programs.

The 1985 legislation was developed during a period of financial stress, crop surpluses, and declining share of world trade. There was extensive debate on the merits of strict supply management versus decoupling. Ultimately, Congress sought middle-ground. The 1985 Food Security Act was designed to be budget-responsible, eliminate surplus stocks, provide stable farm income, and reclaim world market share. In retrospect, it has been relatively expensive, but it has generally met the objective.

Four key factors to be considered during the 1990 farm bill debate are: GATT negotiations, the budget deficit, cropping flexibility, and environmental concerns. Congress could make simple fine-tuning of the 1985 farm legislation to create the 1990 farm bill. Also, we must carefully weigh the political climate. For example, nine of the 19 members of the Senate Agriculture Committee face re-election campaigns. They include members from Arkansas, Alabama, Mississippi, Kentucky, and North Carolina. Also for the first time in modern history, the Chairman of the Senate Agriculture committee is not a southerner and has no specific commodity constituency to serve.

President Bush presented his FY 1991 budget to the Congress in late January. It calls for \$1.2333 trillion in spending, \$1.170 trillion in revenues and a deficit just under the \$64 billion deficit target of the Gramm-Rudman-Hollings budget law. Congress has the responsibility of amending the President's budget and enacting a budget resolution. The budget resolution provides a general guideline to the appropriations committees as they work throughout the spring. The resolution will also contain a reconciliation section requiring Congress to cut spending/increase taxes to meet the \$64 billion deficit target. The reconciliation process will get underway during

the summer. The USDA budget has been proposed to remain at virtually the same level as FY 1990: approximately \$48.5 billion. However, within that amount, farm program spending is slated for a reduction of an additional \$1.5 billion from the estimate of \$11.7 billion in spending. The USDA has not made specific recommendations as to where to reduce farm program spending.

The U.S. has called for multilateral agreement in the Uruguay Round to phase out government-induced trade distortions caused by subsidies and trade restrictions in agriculture. The overall U.S. goal is to level out the international playing field in agriculture, thereby improving competitive conditions for our producers in world markets. Since the talks are scheduled to conclude by the end of 1990, there will have to be substantial progress made in the next few months.

Since GATT negotiations are scheduled for completion by late 1990, there will be spillover from those negotiations to the farm bill debate and vice-versa. The future of U.S. export and import programs will be affected by the response of other nations to a proposal calling for elimination of export subsidies.

In June 1989, the GATT council adopted a panel report on the Australian case challenging the legality of administration of the U.S. sugar import quota imposed under the authority of the tariff schedules. It is important to note that the operation of the sugar price support program was not challenged or found to be inconsistent. The panel did support Australia's position that the U.S. raw/refined import quota is inconsistent with U.S. obligations under GATT international trading rules. Specifically, the panel found the sugar quotas to be inconsistent with Article XI (concerning import quotas) and Article II (concerning qualification to concessions in the tariff schedules of contracting parties). The headnote quota is considered to be inconsistent with Article XI because it is not administered in conjunction with domestic production or marketing controls.

The U.S. accepted the report and is, therefore, expected to end the restriction and/or administer the program in compliance with GATT rules. Acceptance by the U.S. will have a direct effect on the outcome on the Sugar Title of the 1990 farm bill.

As we analyze the farm bill debate, we must acknowledge the role environmental interests will play. The 1985 farm bill set a precedent by linking compliance with "sodbuster" and "swampbuster" regulations to eligibility for program benefits. That linkage could be carried a step further in 1990 by imposing certain recordkeeping provisions on chemical usage, requiring well-testing or even requiring a groundwater management plan to be eligible for program benefits

There was a time when farmers were urged to plant fence-row-to-fence-row. There was a time when federal policy encouraged farmers to fill in wetlands so they could be turned into productive areas. There was a time when agricultural chemicals were promoted as the preferred way to improve crop yields. Those times are no more. Farming, as well as today's farmers, has changed. Farm decisions are increasingly influenced by economics, environmental constraints, and the farmer's own environmental awareness.

America's farmers and ranchers are the most effective producers in the world. At the same time, however, they are some of the most conscientious tillers of the soil, constantly aware of the fragile natural resource that must be preserved for future farm family generations.

Louisiana's sugarcane industry has long realized the importance of dedicated researchers and the beneficial information gained through their work. Several years ago, through a cooperative effort of the Louisiana Farm Bureau Federation and the American Sugarcane League, a voluntary checkoff was established for the purpose of funding necessary research projects. As a matter of fact, approximately \$300,000 was allocated for fiscal year 1990 to fund research projects ranging from agronomic concerns to work dedicated to addressing needs in the processing arena. It is imperative that researchers continue to receive sufficient funding, assuring our industry's needs are adequately addressed, now and in the future.

Maintenance of a viable domestic sugar industry will continue to be dependent upon proper administration of a sugar title similar to the one contained in the Food Security Act of 1985. A program of this type is necessary for our producers to remain economically viable in the face of competition from foreign nations, resulting from programs and policies that include exclusive supply arrangements, dumping of excess production, artificial production incentives, and subsidized exports. These are the ingredients for a year of challenges. Never has it been more important for our industry and the agriculture community to work together to accomplish our objectives.

**PEER REFEREED JOURNAL ARTICLES**



## EFFECTS OF BY-PRODUCT GYPSUM ON SOIL PROPERTIES AND NUTRIENT CONTENT AND YIELD OF SUGARCANE<sup>1/2/</sup>

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### ABSTRACT

An experiment was conducted to determine the effects of by-product fluorogypsum and phosphogypsum ( $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ ) on chemical and physical properties of soil, plant nutrient content and yield components of sugarcane. By-product gypsum was applied to a Sharkey clay soil at rates of 0, 1, 2, 5 and 10 tons/A of fluorogypsum and 5 tons/A of phosphogypsum. Soil samples from the Ap, AC and C soil horizons were analyzed, and leaf-blade nutrients and yield components were measured in plant and first stubble cane crops.

The extractable soil S in the Ap horizon and extractable Ca in the Ap and AC horizons increased with the applied by-product gypsum. The increases were larger in S than Ca due to the inherent low soil S. Extractable Mg decreased in the Ap horizon with the applied gypsum. Other nutrients and heavy metals and the soil physical properties measured were not affected significantly by the applied gypsum.

Significant increases in leaf-blade S were obtained with each gypsum rate in stubble cane but not in plant cane. In plant cane, significant increases were obtained in cane and sugar yields with the 10-ton/A rate over the check and only in cane yield with the 10- over the 2-ton/A of fluorogypsum. In stubble cane, increases were obtained in cane and sugar yields with the 2-, 5- and 10-ton/A rates over the check and only in cane yield with the 5- over the 1-ton/A rate of fluorogypsum. The yields increased with rates higher than a rate normally needed to supply adequate levels of S and Ca, possibly due to improvements in undetermined physical properties in the soil.

The differences in each parameter measured between the fluorogypsum and phosphogypsum were small and not significant.

### INTRODUCTION

By-product gypsum ( $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ ) in the forms of phosphogypsum and fluorogypsum is accumulating in large amounts as a waste material from the production of phosphoric and hydrofluoric acids in Louisiana and other states. Gypsum has been used as a soil amendment to correct S and Ca deficiencies, improve physical properties of alkaline soils and alleviate soil acidity and Al toxicity.

Golden (5) reported increases in soil S and sugarcane yields from the use of phosphogypsum on S deficient clay soils in Louisiana. Oates and Caldwell (7) found that fluorogypsum was more useful than phosphogypsum for alleviating subsoil acidity. Sumner (9) reported improvements in an acid soil profile with surface applications of gypsum.

Most of the gypsum research with sugarcane in Louisiana has been done to correct S deficiencies with the use of low rates of phosphogypsum. The objectives of this research were to study the effects of high rates of fluorogypsum on soil properties and sugarcane grown on a clay soil.

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<sup>2/</sup>Research supported by grant funds from Allied Corporation.



## MATERIALS AND METHODS

A field experiment was conducted to determine the effects of rates of by-product gypsum on chemical and physical properties of soil, nutrient content and yield components of sugarcane. The test was located on a Sharkey clay soil on Cinclare Plantation near Port Allen, La. The Sharkey soil is a very fine montmorillonitic clay with distinct Ap, AC and C horizons containing 62, 66 and 78 percent clay, respectively.

The rates of by-product gypsum tested were 0, 1, 2, 5 and 10 tons/A of fluorogypsum and 5 tons/A of phosphogypsum for comparison purposes. The gypsum treatments were broadcasted and incorporated into the topsoil, and cane variety CP 72-356 was planted in the fall of 1985. The treatments were placed in a randomized block design with four replications. Each plot was three rows wide and 75 feet long with border rows between plots. Fertilization and cultural practices were used according to recommendations.

An analysis of the two types of by-product gypsum used in the experiment and mined gypsum for comparison purposes is shown in Table 1. The by-product types contain similar amounts of Ca, but fluorogypsum contains more S than phosphogypsum. Each contains low concentrations of other nutrients and heavy metals.

Table 1. Analysis of the two types of by-product gypsum used in the experiment and mined gypsum for comparison purposes. <sup>1/</sup>

Element	Unit	By-Product		Mined Gypsum
		Fluorogypsum	Phosphogypsum	
Ca	percent	20.97	21.15	17.43
S	percent	16.23	12.46	14.20
Si	percent	3.91	16.87	13.75
<hr/>				
P	ppm	82	2188	110
Na	ppm	2500	2350	3425
Fe	ppm	540	3218	5048
Al	ppm	1000	1950	4400
Ni	pp	13	17	17
Pb	ppm	6	< 1	6
Hg	ppm	< 1	< 1	< 1
As	ppm	< 1	< 1	6
Cd	ppm	< 1	< 1	< 1

Analysis was made by Pembroke Laboratory, 528 Gooch Rd., Fort Meade, Fla.

Yield components and nutrient concentrations in leaf blades were measured at harvest time in plant cane in 1986 and first stubble cane in 1987. Soil samples were taken from the Ap, AC and C horizons to a 30-inch depth in each plot in June, 1986. Extractable soil cations and P and soil pH were determined by methods used in the LSU Soil Testing Laboratory (8). Sulfur was extracted using the Bardsley and Lancaster method (2). Micronutrients and Pb were extracted using the DTPA method (1), and other heavy metals were extracted by the 0.1N HCl method. The plant and soil sample extracts were analyzed with an ICP spectrophotometer.

Several physical properties of the soil were measured on each plot. Root density was measured by washing and weighing roots in a soil sample. Particle size was determined by the pipette method and particle density by the pycnometer method (3). Hydraulic conductivity was measured using the constant-head method (6) and bulk density by the volume-weight method on undisturbed soil cores. Mechanical impedance was determined in the field using the penetrometer method (4).

An analysis of variance was made for each parameter measured, and Tukey's HSD method was used to test for significance between treatment means.

## RESULTS AND DISCUSSION

### Soil Chemical Properties

The effects of rates of by-product gypsum on the extractable soil nutrients and soil pH in the Ap, AC and C horizons are shown in Table 2. The measurements were made 10 months after the gypsum application. The extractable S was relatively low in each horizon on the check plot. In the Ap horizon, S increased significantly with the 5 and 10 tons/A rates over the 0, 1- and 2-ton/A rates of fluorogypsum. In the AC and C horizons, the differences in S due to gypsum rates were not significant. As an average of horizons, the S increased with the 5-ton rate over the check and with the 10-ton rate over the 0, 1- and 2-ton rates.

Table 2. Effects of rates of by-product gypsum on extractable soil nutrients and soil pH on a Sharkey clay soil, 1986.

By-product gypsum applied <sup>1/</sup>	Soil Horizon	Extractable soil nutrient						Soil pH
		S	Ca	Mg	P	K	Na	
Tons/A		-----ppm-----						
0	Ap	13	5906	1252	140	451	75	6.0
	A-C	10	6682	1382	112	486	116	6.8
	C	10	7494	1480	161	503	150	7.3
	Ave.	11	6694	1371	137	480	114	6.7
1	Ap	39	6254	1228	136	431	71	6.1
	A-C	18	7093	1409	113	456	117	6.9
	C	14	7391	1497	161	489	155	7.5
	Ave.	24	6912	1378	136	469	114	6.8
2	Ap	179	6941	1172	149	437	63	6.0
	A-C	19	7183	1406	110	452	107	6.9
	C	14	7674	1522	154	497	150	7.4
	Ave.	71	7266	1366	138	462	107	6.8
5	Ap	742	7786	1161	138	450	67	6.0
	A-C	189	7178	1382	107	433	104	6.7
	C	72	7946	1497	153	506	147	7.4
	Ave.	334	7637	1347	133	463	106	6.7
5 P	Ap	544	7563	1145	135	432	64	5.9
	A-C	93	7209	1383	114	433	112	6.7
	C	20	7795	1510	147	512	156	7.5
	Ave.	219	7522	1346	132	459	111	6.7
10	Ap	1125	9136	1135	120	435	67	6.0
	A-C	178	7445	1363	94	432	118	6.8
	C	77	7667	1495	153	490	158	7.5
	Ave.	460	8083	1331	122	452	114	6.7
HSD 0.5 Horizon		541	745	102	39	72	29	0.3
HSD .05 Treat. Average		313	430	NS	NS	NS	NS	NS

<sup>1/</sup> Fluorogypsum was used for all treatments, except phosphogypsum was used for the 5P treatment.

The extractable Ca was relatively high on all the plots and significantly increased with depth in the check plot and decreased with depth with the 10-ton rate of fluorogypsum. In the Ap horizon, Ca increased with the 2-, 5- and 10-ton rates over the check and with the 5- and 10-ton rates over the 1-ton rate. In the AC horizon, Ca increased with the 10-ton rate over the check. In the C horizon, the differences in Ca were small. As an average of horizons, the Ca increased with the 2-, 5- and 10-ton rates over the check, with the 5- over the 1-ton rate and with the 10- over the 1-, 2- and 5-ton rates of gypsum.

Extractable Mg was relatively high and increased with depth on all the plots. In the Ap horizon, Mg decreased with the 10-ton rate over the check plot. The gypsum rates did not affect Mg levels in the other horizon nor the average of horizons. Oates and Caldwell (7) also reported a reduction in exchangeable Mg with gypsum treatments. Apparently, some Mg was displaced by Ca on the cation exchange capacity, but this is not a problem in soil with high Mg levels. Generally, the extractable P, K and Na and soil pH increased with depth in the soil but were not affected by the gypsum treatments. Since  $\text{CaSO}_4$  in gypsum is essentially a neutral salt, it has little effect on soil reaction near pH 7.

The effects of by-product gypsum on selected extractable micronutrients and heavy metals in the soil are reported in Table 3. The Fe, Cu, Zn and Mn micronutrients and As, Cd, Pb and Ni heavy metals were not increased in the soil with the application of relatively high rates of fluorogypsum and phosphogypsum. One possible exception is that the As increased slightly with the 10-ton/A rate of fluorogypsum. Only small amounts of these elements are contained in by-product and mined gypsum (Table 1).

Table 3. Effects of rates of by-product gypsum on extractable micronutrients and heavy metals in a Sharkey clay soil, 1986.

By-product gypsum applied <sup>2/</sup>	Soil extractable <sup>1/</sup>							
	Micronutrients				Heavy metals			
	Fe	Cu	Zn	Mn	AS	CD	Pb	Ni
Tons/A	ppm							
0	77	6.4	2.3	23	9.0	0.3	3.3	2.2
1	74	6.5	2.2	23	8.8	0.3	3.4	2.1
2	69	7.3	2.3	22	8.8	0.3	3.4	2.1
5	79	7.3	2.4	25	9.3	0.3	3.4	2.1
5 P	77	6.5	2.2	22	8.8	0.3	3.3	2.1
10	74	7.2	2.2	21	9.9	0.3	3.3	2.0
HSD .05	NS	NS	NS	NS	1.0	NS	NS	NS

1/ Average of Ap, AC and C soil horizons.

2/ Fluorogypsum was used for all treatments, except phosphogypsum was used for the 5 P treatment.

Generally, the differences in the soil chemical properties between the two types of by-product gypsum were small. The extractable S was slightly lower with the phosphogypsum than the fluorogypsum treatments due to a lower percent S in phosphogypsum.

### Soil Physical Properties

The effects of the gypsum treatments on the physical properties measured in the Sharkey clay soil were small and not significant. There were increasing trends in root density with increasing gypsum rates in each crop year. The particle-size distribution and particle density in the soil are inherent properties and were not affected by the gypsum treatments. The percent clay increased with depth from 61.8% in the Ap to 77.6% in the C horizon. Bulk density, hydraulic conductivity and mechanical impedance were not improved with the relatively high rates of gypsum. These properties are affected by gypsum principally on alkaline soils.

### Nutrient Content of Leaf Blades

The effects of rates of by-product gypsum on the S, Ca, Mg, P and K concentrations in leaf blades of plant and stubble cane are reported in Table 4. The effects of gypsum on each nutrient were small in both crops except for S and Ca in first stubble cane. Significant increases in leaf-blade S were obtained from each gypsum rate over the check and with the 10- over the 1-ton/A rate in stubble cane. Significant correlations were found between the gypsum rates and S ( $r = .877$ ) and Ca ( $r = .566$ ) in the leaf-blades. The differences were larger, and correlation coefficients with gypsum rates were higher with S than Ca. Apparently, this was due to the relatively low S and high Ca levels in the soil.



Table 4. Effect of rates of by-product gypsum on the nutrient concentration in leaf blades of plant and first stubble cane on a Sharkey clay soil, 1986-87.

By-product gypsum applied <sup>1/</sup>	Nutrients in leaf blades				
	S	Ca	Mg	P	K
Tons/A	-----percent-----				
	<u>Plant cane</u>				
0	.255	.420	.106	.138	1.400
1	.254	.418	.100	.127	1.323
2	.247	.442	.104	.138	1.302
5	.257	.428	.103	.138	1.394
5 P	.263	.437	.105	.133	1.399
10	.263	.442	.102	.143	1.423
HSD .05	NS	NS	NS	NS	NS
	<u>Stubble cane</u>				
0	.143	.280	.090	.151	1.217
1	.169	.289	.084	.151	1.191
2	.180	.303	.087	.149	1.194
5	.185	.308	.084	.153	1.242
5 P	.179	.295	.084	.152	1.194
10	.195	.309	.087	.155	1.235
HSD .05	.021	NS	NS	NS	NS

<sup>1/</sup> Fluorogypsum was used for all treatments, except phosphogypsum was used for the 5 P treatment.

#### Yield of Sugarcane

The effects of rates of gypsum on yield components in plant and first stubble cane are shown in Table 5. In plant cane, significant increases were obtained in cane and sugar yields with the 10-ton/A rate over the check and only in cane yield with the 10- over 2-ton/A rate of fluorogypsum. In stubble cane, increases were obtained in cane and sugar with yields 2-, 5- and 10-ton/A over the check and only in cane yield with the 5- over the 1-ton/A rate of fluorogypsum. The yield increases were due principally to increases in individual stalk weight and length in plant cane and to increases in stalk population and weight in stubble cane. The juice quality in both crops was not significantly affected by the gypsum treatments. Highly significant correlations were obtained between rates of fluorogypsum and yield of plant cane ( $r = .777$ ) and yield of stubble cane ( $r = .862$ ). The differences in each yield component between the fluorogypsum and phosphogypsum at the 5-ton/A rate were small.



Table 5. Effect of rates of by-product gypsum on the yield components of plant and first stubble cane on a Sharkey clay soil in 1986-87.

By-product gypsum applied <sup>1/</sup>	Cane Yield	Millable stalk			Normal juice		Sugar Yield
		No.	Wt.	Length	Brix	Sucrose	
Ton/A	T/A	1000/A	lbs.	in.	%	%	lbs./A
<u>Plant cane</u>							
0	39.0	32.0	2.44	88.5	17.1	14.3	7989
1	42.4	33.1	2.57	90.8	17.1	14.4	8722
2	41.8	32.1	2.61	91.1	17.0	14.2	8502
5	43.0	31.3	2.75	94.3	17.6	14.7	9045
5 P	43.2	32.0	2.74	90.6	17.2	14.5	8997
10	46.7	32.5	2.88	94.1	16.9	14.2	9432
HSD .05	4.8	NS	0.34	5.7	0.6	NS	1101
<u>Stubble cane</u>							
0	16.8	18.5	1.81	70	17.4	13.4	3156
1	19.4	20.3	1.92	71	17.6	13.6	3747
2	22.1	21.5	2.06	74	17.1	13.2	4082
5	24.0	22.7	2.13	75	17.4	13.5	4566
5 P	24.4	22.3	2.19	74	17.1	13.3	4550
10	23.6	23.2	2.03	74	16.9	12.9	4263
HSD .05	4.6	3.6	0.31	NS	NS	NS	904

<sup>1/</sup> Fluorogypsum was used for all treatments, except phosphogypsum was used for the 5 P treatment.

## CONCLUSIONS

The application of by-product gypsum on a Sharkey clay soil significantly affected the extractable soil S, Ca and Mg, leaf-blade S and yield of sugarcane. The extractable S in the Ap horizon and Ca in the Ap and AC horizons increased with applied gypsum. The increases were larger in S than Ca, apparently due to the inherent low S level in the soil.

Extractable Mg decreased in the Ap horizon, apparently due to the large amount of Ca in the applied gypsum, but it was not decreased to a deficient level. Other nutrients and heavy metals in the soil were not affected significantly by the gypsum treatments. High rates of by-product gypsum containing small amounts of heavy metals did not create a hazardous problem in the soil. Although the soil physical properties measured were not affected significantly, there was an increasing trend in root density with increasing gypsum rates.

Significant increases in leaf-blade S were obtained with each gypsum rate in stubble cane, but not in plant cane. Significant increases in cane and sugar yields were obtained from the gypsum treatments in plant and stubble cane. The yields increased with gypsum rates higher than a rate normally needed to supply adequate levels of S and Ca in the soil. These yield increases were possibly due to improvements in undetermined soil physical properties related to increasing trends in root density.

The differences in soil properties, leaf nutrients and yield components between the phosphogypsum and fluorogypsum at a 5-ton/A rate were small and not significant.

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**INFLUENCE OF SEEDPIECE TREATMENT AND SEEDING DENSITY  
ON STALK POPULATION AND YIELD OF A PINEAPPLE DISEASE  
SUSCEPTIBLE SUGARCANE CULTIVAR**

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**ABSTRACT**

Fungicidal treatments of sugarcane seedpieces in combination with two seedpiece densities were evaluated for control of pineapple disease, caused by *Ceratocystis paradoxa*. Propiconazole was applied either as a seedpiece dip or as an in-furrow spray application at one of three different rates to the pineapple disease susceptible cultivar, CP 74-2005. Millable stalk populations, tons of cane per hectare, and sugar per hectare were consistently higher in all fungicide treatments than in the nontreated check, regardless of seedpiece density. In general, dip application appeared to be more efficacious than in-furrow spray application. A comparison of stalk populations and yields obtained from planting a single line of dip-treated seed with those of the industry standard, a double line of untreated seedpieces, indicates that treatment of seedpieces with a fungicide may enable Florida sugarcane growers to reduce seeding density without sacrificing stalk populations and yields.

**INTRODUCTION**

Pineapple disease, incited by the fungus *Ceratocystis paradoxa* (Dade) C. Moreau, can cause significant sugarcane (interspecific hybrids of *Saccharum*) stand reductions (18). The most serious losses are through the failure of infected seedpieces to germinate (18), although standing cane may also become infected (8,9). A wide range in cultivar susceptibility has been reported (12,17). In Florida, two cultivars of commercial significance, CP 74-2005 and CP 72-2086, are highly susceptible to this disease (4). Together, these two cultivars accounted for 10.3% of the Florida sugarcane hectareage in 1989 (5). On the organic soils of the Everglades Agricultural Area (EAA), disease development appears to be most favored by cool, wet soil conditions (4). Although Florida's dry season generally coincides with the cool winter months (December - February), heavy localized rainfalls during this period are not uncommon. Stand reductions due to pineapple disease of severities sufficient to require selective replanting have been observed in poorly drained fields in the EAA.

A number of control measures have been recommended for pineapple disease, including the use of resistant cultivars, site selection, increased seedpiece length, and avoidance of factors which slow seedpiece germination (18). In many cane-growing regions of the world, seedpieces are routinely treated with a fungicide as part of the planting operation (7,14,15,16). In Florida, where seedpiece treatment is not practiced, seedpieces are typically overlapped and at least doubled in the furrow at planting. This practice is to insure establishment of an adequate number of primary shoots. When a pineapple disease susceptible cultivar is being planted under conditions favorable for disease development, the seeding density may be further augmented. Although pineapple disease is widespread in Hawaii (13) and Australia (1), the standard planting procedure involves only a single line of fungicide-treated seedpieces per row. This seeding rate, in combination with seedpiece treatment, is capable of producing stands sufficient for maximizing yields.

Planting costs are second only to harvesting costs in terms of sugarcane production expenses (2). By reducing seedpiece density, growers could realize a savings in seed costs, transportation costs, and overall labor and handling costs. In addition, cane that would normally be used for seed could be milled for sugar. However, these prospects can not be realized if seedpiece treatments do not provide adequate stands at reduced seedpiece density. The objectives of this experiment were: 1) to investigate the efficacy of various



seedpiece fungicide treatments on stalk population and yield, and 2) to investigate the feasibility of reducing seedpiece density by utilizing fungicide-treated seedpieces.

## MATERIALS AND METHODS

The pineapple disease susceptible sugarcane cultivar CP 74-2005 was planted on 7 January, 1989 in a 0.27 ha plot located in a commercial sugarcane field. The study was planted as successive-planted cane to enhance disease pressure exerted by *C. paradoxa*. Soil was classified as 'Okeelanta muck' (Euic hyperthermic Terric Medisaprist) with a pH of 6.5. Treatments were arranged as randomized complete blocks in a split-plot design with six replications. Main plots consisted of a single-line or a double-line of seedpieces planted per row. Subplots received one of six seedpiece treatments (Table 1). Propiconazole (1-[[2-(2,4-dichloro-phenyl) -4-propyl-1,3- dioxolan -2-yl]methyl]-1H-1,2,4-triazole), the only fungicide used in the experiment, has been demonstrated to be efficacious in controlling pineapple disease in other areas (3,6,7,16). Treatments receiving no fungicide served as the control. Fungicide treatments varied by application method, application rate, or spray volume (Table 1). In-furrow sprays were applied as a 15-cm-width band over the seedpiece using a CO<sub>2</sub> backpack sprayer equipped with a flat-fan nozzle at 138 kPa. Dip treatment was performed by immersing seedpieces in a 25 ppm propiconazole suspension at ambient temperature for 5 min. Treatment subplots consisted of two 12.1 m rows with 1.5 m row spacing. Seedpieces were 45 to 60 cm in length with approximately four to six nodes per piece. Overhead irrigation (approximately 7.5 cm) was applied to the entire experimental area on 7-10 January, 1989 to favor pineapple disease development. Numbers of emerged shoots and harvestable stalks were recorded on 20 April and 28 August, respectively. Yield estimates were obtained from stalk samples (20 stalks/subplot) cut and milled on 26 January, 1990.

Table 1. Effect of seedpiece treatment and seeding density<sup>1</sup> on shoot counts and millable stalk populations of cultivar CP 74-2005.

Treatment	Method <sup>2</sup>	Rate (A.i.)	Volume <sup>3</sup> (L/ha)	Shoot counts <sup>4</sup>		Millable stalk pop. <sup>5</sup>	
				Single	Double	Single	Double
Nontreated	---	---	---	8,821	15,879	35,960	48,362
Propiconazole	dip	25 ppm	---	14,425	25,011	54,537	68,755
Propiconazole	Spray	126 g/ha	187	10,378	18,473	42,550	55,212
Propiconazole	Spray	186 g/ha	187	10,690	18,525	44,419	57,910
Propiconazole	Spray	252 g/ha	187	10,326	19,874	45,923	58,118
Propiconazole	Spray	252 g/ha	374	11,468	20,081	46,027	59,778
LSD (P = 0.05)				2,769	4,563	8,092	8,311

<sup>1</sup> Single or double lines of vegetative seedpieces in the furrow at time of planting.

<sup>2</sup> Method of chemical treatment. Dip application consisted of a 5 min seedpiece dip in a fungicide suspension at ambient temperature. Sprays were applied in-furrow as directed (10-20 cm band) sprays applied with a CO<sub>2</sub> backpack sprayer at 138 kPa.

<sup>3</sup> Spray volume of fungicide used. Water was used as the carrier.

<sup>4</sup> Total shoot numbers on 20 March, 1989.

<sup>5</sup> Number of millable stalks/ha on 28 August, 1989.



## RESULTS AND DISCUSSION

Warm temperatures and abnormally dry conditions throughout the spring of 1989 tempered the impact of pineapple disease in the experimental area, despite attempts to create favorable disease conditions with overhead irrigation. However, excavation of nongerminated seedpieces from areas immediately surrounding the experiment showed pineapple disease was present and limited germination. Analysis of variance indicated highly significant ( $P \leq 0.001$ ) main plot effects (seeding density) and subplot effects (seedpiece treatment) for shoot and millable stalk populations (Table 1), cane per unit area, and sugar per unit area (Table 2). With respect to the main effect, increasing the seeding density from one to two lines of seedpieces per row provided for significant increases in stalk populations and yield ( $P \leq 0.05$ ); however, increases were not in direct proportion to the increase in seed density. One possible explanation for this result is that increased competition among developing tillers under higher populations may have negated some of the desired effects of planting a double line of seedpieces.

Table 2. Effect of seedpiece treatment and seeding density<sup>1</sup> on cane per unit area and sugar per unit area of cultivar CP 74-2005.

Treatment	Method <sup>2</sup>	Rate (a.i.)	Volume <sup>3</sup> (L/ha)	Cane per unit area (Mt/ha)		Sugar per unit area (kg/ha)	
				Single	Double	Single	Double
Nontreated	---	---	---	41.4	51.8	4,858	6,075
Propiconazole	Dip	25 ppm	---	60.4	73.1	7,074	8,564
Propiconazole	Spray	126 g/ha	187	46.3	61.2	5,426	7,178
Propiconazole	Spray	186 g/ha	187	48.1	64.2	5,634	7,528
Propiconazole	Spray	252 g/ha	187	49.8	61.0	5,839	7,154
Propiconazole	Spray	252 g/ha	374	51.1	65.1	6,004	7,634
LSD ( $P = 0.05$ )				10.3	10.6	1,212	1,237

<sup>1</sup> Single or double lines of vegetative seedpieces in the furrow at time of planting.

<sup>2</sup> Method of chemical treatment. Dip application consisted of a 5 min seedpiece dip in a fungicide suspension at ambient temperature. Sprays were applied in-furrow as directed (10-20 cm band) sprays applied with a CO<sub>2</sub> backpack sprayer at 138 kPa.

<sup>3</sup> Spray volume of fungicide used. Water was used as the carrier.

Significant seeding density X seedpiece treatment interactions were not detected with regard to stalk populations or yield. The propiconazole seedpiece dip treatment provided for significantly higher shoot counts and stalk populations than the nontreated check or fungicide in-furrow spray treatments, regardless of seeding density (Table 1). Although differences were not always significant, propiconazole in-furrow spray treatments provided for higher shoot and stalk populations than the nontreated check, with populations increasing as fungicide rates increased. Differences among treatments in mean stalk fresh weight or sucrose levels were insignificant at the  $P \leq 0.05$  level and therefore are not presented. With respect to cane per unit area and sugar per unit area, the dip treatment consistently provided for the highest yields (Table 2). Cane and sugar yields of in-furrow spray treatments were generally higher than those of the nontreated check, although not always statistically ( $P \leq 0.05$ ). These data generally corroborate those recorded in previous greenhouse and field experiments (10).

A comparison of stalk populations and yields obtained with the two 252 g a.i./ha propiconazole in-furrow sprays at different volumes suggests that increasing the spray volume may be a method of increasing the efficacy of this particular application technique (Table 1 and 2). This is not surprising, since the added volume of carrier would most likely result in improved coverage. Although propiconazole is systemic in nature, the seedpiece endcut is the infection site of primary importance (18), and coverage of this area is critical.

The influence of seeding density and seedpiece treatment on stalk populations and sugar yield, relative to the industry standard of a double line of untreated seedpieces, is presented in Table 3. Results indicate that a single line of propiconazole dip-treated seedpieces provided for higher stalk populations and sugar yield than the industry standard. Technological improvements for in-furrow spray applications are possible. Improving the efficacy of an in-furrow spray application to a level comparable to dip application would broaden the appeal of a seedpiece fungicide treatment to the sugarcane industry.

Table 3. Relative influence of seeding density<sup>1</sup> and seedpiece fungicide treatments on stalk populations and sugar per unit area relative to the industry standard, a double line of untreated seedpieces of cultivar CP 74-2005.

Treatment	Method <sup>2</sup>	Rate (a.i.)	Volume <sup>3</sup> (L/ha)	Percent difference <sup>4</sup>			
				Stalk populations		Sugar per unit area	
				Single	Double	Single	Double
Nontreated	---	---	---	- 25.6	0.0	- 20.0	0.0
Propiconazole	Dip	25 ppm	---	+ 12.8	+ 42.2	+ 16.4	+ 41.0
Propiconazole	Spray	126 g/ha	187	- 12.0	+ 14.2	- 10.7	+ 18.2
Propiconazole	Spray	186 g/ha	187	- 8.2	+ 19.7	- 7.3	+ 23.9
Propiconazole	Spray	252 g/ha	187	- 5.1	+ 20.2	- 3.9	+ 17.8
Propiconazole	Spray	252 g/ha	374	- 4.8	+ 23.6	- 1.2	+ 25.7

<sup>1</sup> Single or double lines of vegetative seedpieces in the furrow at time of planting.

<sup>2</sup> Method of chemical treatment. Dip application consisted of a 5 min seedpiece dip in a fungicide suspension at ambient temperature. Sprays were applied in-furrow as directed (10-20 cm band) sprays applied with a CO<sub>2</sub> backpack sprayer at 138 kPa.

<sup>3</sup> Spray volume of fungicide used. Water was used as the carrier.

<sup>4</sup> Percent increase (+) or decrease (-) relative to the millable stalk population or amount of sugar produced by planting a double row of untreated seedpieces of cultivar CP 74-2005.

Results of this study are encouraging with respect to future prospects for reducing seeding density and maintaining yields by seedpiece fungicide dip treatment. Numerous freezes during the past several decades have resulted in seedcane shortages, producing demands for even poor quality seedcane. The availability of an efficacious seedpiece treatment during such instances could prove invaluable. Seedpiece treatment could allow growers to extend the hectareage planted from a limited amount of cane seed.

It should be noted that these results were obtained with a single pineapple disease susceptible cultivar. An effort was made to test the numerous seedpiece treatments under favorable disease conditions so that their performance could be measured under adverse conditions. Relative differences obtained using treated and nontreated seedpieces of a resistant cultivar would most likely be less than those reported herein. In addition, reducing seedpiece density would increase the relative importance of controlling other factors that may influence germination and emergence, such as soil insect pest populations, seed cane quality, and seed handling. Further testing is necessary.

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EVALUATION OF TWELVE FLORIDA SUGARCANE CULTIVARS FOR  
DISEASE SEVERITY AND HOST RESPONSE TO  
*PUCCINIA MELANOCEPHALA*<sup>1</sup>

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ABSTRACT

Twelve commercial sugarcane cultivars were assessed for rust severity and host response resulting from natural infection by *Puccinia melanocephala* during 1988 and 1989. Analysis of variance indicated significant ( $P \leq 0.05$ ) cultivar and year influences on both severity and response. A significant cultivar X year interaction was also observed. Mean rust severities ranged from a low of 0.4% on CP 70-1133 to 39% on CP 78-1247 during 1988. Rust severities were less on all cultivars during 1989, ranging from 0% on CP 78-2114 to 5.4% on CP 72-1210. Of the cultivars examined, CP 78-1247, CP 72-1210, CL 73-239, CP 70-1527, and CP 74-2005 exhibited sporulating pustules during 1988. Pustules were not observed on CP 70-1527 during 1989. Shifts in the ranking of cultivars in terms of susceptibility were observed.

INTRODUCTION

Sugarcane rust, caused by the fungus *Puccinia melanocephala* H. & P. Syd., is one of Florida's most serious sugarcane (*Saccharum* spp.) diseases (18). Since its introduction into the Caribbean in 1978 and into Florida the following year (7), rust epidemics have become an annual occurrence, differing only in the extent of their intensity (11). Reports of serious yield losses caused by sugarcane rust abound, particularly following the initial introduction of the pathogen into a geographical region (25). The cultivar B 4362, reported by Ryan and Egan (25) as the most susceptible major cultivar known, experienced cane yield losses of up to 50% or more in Cuba and Mexico during the late 1970s and early 1980s (19).

Although a number of fungicides have been demonstrated as efficacious in controlling rust (2, 25), cultivar resistance remains as the only economically feasible control (15). Over the years, *P. melanocephala* has caused the loss of a number of prominent cultivars which proved to be susceptible (25). Most notable of the cultivars withdrawn from production are Co 475 in India (27), B 4362 in Cuba and Mexico (6), Q 90 in Australia (8), and CL 41-223 in Florida (6). One disturbing aspect involving resistance has been the apparent development of susceptible-type reactions by cultivars previously reported as resistant (16). Circumstantial evidence for the existence of sugarcane rust races has been presented (4,5,6,20). However an established set of host differentials for identification of races, such as those that exist for the various cereal rusts (12,24), has never been established for sugarcane.

There has been very little effort to quantitatively document the susceptibility of various sugarcane cultivars to rust in Florida over the past decade. Information gained by establishing a data base on cultivar susceptibility over time could prove invaluable in assisting to accomplish the following: 1) identifying durable resistance, 2) documenting the existence of races of *P. melanocephala*, and 3) detecting changes in cultivar susceptibility at an early stage, thus avoiding serious losses in the future.

MATERIALS AND METHODS

Twelve commercial sugarcane cultivars were established in a randomized complete block design in a 1.1 ha field at the Everglades Research and Education Center, Belle Glade. A double line of seedcane was planted on 22 December, 1987 with a 1.5 m row spacing. The organic soil was classified as a 'Pahokee Muck' with a pH of 6.2 and was fertilized with 588 kg/ha of 0-10-40 fertilizer with recommended minor elements prior to planting. Cultivar treatments were replicated three times and consisted of three rows of cane 61 m long. Plantcane was harvested mechanically on 22 January, 1989.

<sup>1</sup> Florida Experimental Station Journal Series No. R-00875.



Sugarcane rust was assessed for severity and reaction type on 16 and 28 June during 1988 and 1989, respectively. Rust severities were those arising from natural levels of inoculum. June was selected for observations since rust epidemics in Florida frequently peak during May and June and subsequently decline due to unfavorable temperatures (8). Ratings both years were made at growth stage 4 (3), when the cane was 1.5 to 2.0 m in height. All rust severity ratings were performed on the top visible dewlap (TVD) leaf on a leaf segment 30 cm in length located at the distal third of the leaf. The rated leaf segment was located basipetal to the point measured from the leaf tip where leaf width was a minimum of 1.25 cm. Standard area diagrams for sugarcane rust were used to aid the visual assessment of severity on a percentage scale (17). Four randomly selected leaves were sampled per row of cane. Host response ratings as they relate to symptom development were also recorded as described by Purdy and Dean (17).

## RESULTS AND DISCUSSION

Conditions for rust development during 1988 were very favorable with the absence of freezes during the winter and spring seasons. Normal temperatures coupled with the relative lack of rainfall during the spring promoted widespread dissemination of rust throughout the Everglades Agricultural Area (EAA). In 1989, a late winter frost occurred on 25 February. This resulted in desiccation of massive amounts of leaf tissue supporting infections at the time of the frost and delayed the onset of the annual epidemic. Rust intensities observed in commercial production fields throughout the EAA during Spring 1989 were greatly reduced relative to the previous year.

There was a wide range in cultivar rust susceptibility as indicated by host response and disease severity (Table 1). Analysis of variance indicated highly significant differences ( $P \leq 0.01$ ) among cultivars and between years in both severity and response. Cultivar X year interactions were also highly significant.

Rust severity was less on every cultivar in 1989 than during 1988. Mean rust severities across cultivars were 7.7 % and 1.4 % for 1988 and 1989, respectively. These reductions in mean severity may be reflective of the influence of several factors: 1) intensity of the area-wide rust epidemics during the respective years, and 2) differential reductions in cultivar susceptibility of ratoon crops to rust in comparison to plantcane (1). However, shifts in severity ranking of cultivars across years indicate that other influences also may be operative. The presence of multiple physiological rust races or the differential responses of certain cultivars to varying levels of inoculum are two possibilities.

As with rust severity, overall host response ratings were higher during 1988 than in 1989, being 3.8 and 3.1, respectively (Table 1). Cultivars CP 78-1247, CP 72-1210, CL 73-239, CP 70-1527, and CP 74-2005 exhibited sporulating pustules during 1988, with the remaining cultivars exhibiting a range of chlorotic to necrotic flecks. During 1989, pustules failed to form on CP 70-1527, although sporulation was again observed on the other cultivars just mentioned. Changes in cultivar response over time were reported for cultivars CP 78-1247, CP 72-1210, CP 70-1527, CL 61-620, CP 73-1547, CP 80-1827, and CP 78-2114 with a decrease in the degree of symptom expression over time in all cases.

Of the five cultivars exhibiting sporulating lesions during the course of this study, two were reported as resistant (CP 72-1210 and CP 74-2005) and two were reported as moderately susceptible (CL 73-239 and CP 70-1527) at the time of release (13,14,26). Cultivars CL 73-239 and CP 70-1527 could be described as tolerant, since favorable yields were maintained despite higher rust levels. CP 78-1247 was reported to have light infections at only two of eight test locations just prior to its release in 1986 (23). During 1988, CP 78-1247 exhibited severe infection and profuse sporulation throughout the EAA, consistent with observations in this study. However, levels of rust observed on CP 78-1247 throughout the EAA during spring 1989 were very location dependent (R. Raid, unpublished). In contrast to the relatively low severity reported at this location (1.2%), rust severities in excess of 50% were observed at scattered locations throughout the Everglades. The year and location dependency of rust severity in CP 78-1247 gives added credibility to a hypothesis concerning physiological (pathological) variation in *P. melanocephala*. A similar situation occurred with CP 79-1580 and was documented by Dean and Purdy (6).

The resistance of CP 70-1133 and CL 61-620 to rust in this experiment is consistent with area-wide observations on these particular cultivars. Although CP 70-1133 and CL 61-620 were released for commercial production prior to the introduction of rust in Florida (10,23), sporulating pustules have only occasionally been reported on both cultivars over the years, and at very low severities. The apparent durability of their resistance should provide sugarcane breeders with a measure of optimism. The stability of rust resistance on CP 80-1743, CP 73-1527, CP 80-1827, CP 72-2086, and CP 78-2114 remains to be seen.

Table 1. Rust severity and host response of twelve commercial sugarcane cultivars grown in Belle Glade, Florida during 1988 and 1989.

Cultivar	Rust severity <sup>1</sup> (%)		Host response <sup>2</sup> rating	
	1988	1989	1988	1989
CP 78-1247	38.6	1.2	7.0	5.3
CP 72-1210	16.9	5.4	6.2	5.8
CL 73-239	11.4	4.8	5.0	5.0
CP 70-1527	9.7	0.3	5.3	2.0
CP 74-2005	5.7	4.1	5.3	5.3
CL 61-620	2.9	0.4	2.7	2.3
CP 80-1743	2.1	0.0	2.0	2.0
CP 73-1547	2.1	0.1	3.8	2.0
CP 80-1827	1.7	0.1	2.7	2.0
CP 78-2114	0.9	0.0	2.0	1.3
CP 72-2086	0.6	0.1	2.0	2.0
CP 70-1133	0.4	0.1	2.0	2.0
Statistical significance level <sup>3</sup>				
Cultivar	0.01		0.01	
Year	0.01		0.01	
Cultivar x year	0.01		0.01	

<sup>1</sup> Mean percent leaf area affected by rust on 12 leaves per plot. Assessments were performed on the distal third of the topmost fully-expanded leaf.

<sup>2</sup> Symptom expression based upon host response on the topmost fully-expanded leaf (17). Types: 1 - Chlorotic flecks only; 2 - Chlorotic flecks with red or brown centers; 3 - Small to large irregularly shaped spots that coalesce with pustules absent; 4 - Individual chlorotic or red spots with nonopened pustules; 5 - Individual chlorotic or red spots with pustules producing spores; 6 - Blotches of leaf reddened or necrotic with pustules producing spores; 7 - Coalesced red to brown blotches or spots covering much leaf surface and with pustules producing spores.

<sup>3</sup> Significance level determined by analysis of variance.

More recent observations on sugarcane rust in the EAA indicate that rust severities on CP 74-2005 and CL 73-239 surpassed those observed on CP 72-1210 during spring 1990 (R. Raid, unpublished data). Of the cultivars exhibiting sporulating pustules during 1988 and 1989, only these two cultivars did not show a decrease in host response, despite the decline in overall disease pressure. Although speculative, it is not inconceivable that a trend towards increased susceptibility of these two cultivars is in progress.

Given the past instability of rust resistance on a number of cultivars, it is unlikely that the results reported herein will be fully applicable 10 years from now. However, our goal is that results of standardized cultivar assessments such as these will be utilized in the establishment of a permanent sugarcane rust/cultivar database for Florida cultivars. By documenting changes in host response and susceptibility over time, nonspecific resistance, or at the very least, important trends may be identified.

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## SUGARCANE YIELD RESPONSE TO SOIL INSECTICIDES IN THE EVERGLADES AGRICULTURAL AREA<sup>1</sup>

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### ABSTRACT

Sugarcane (*Saccharum* spp.) grown on Histosols (organic soils) in the Everglades Agricultural Area (EAA) is attacked by two major groups of soil insect pests: wireworms (Order Coleoptera, Family Elateridae) and white grubs (Order Coleoptera, Family Scarabaeidae). The objective of this research was to evaluate sugarcane yield response to soil insecticides applied at planting for wireworm control. Evaluations were conducted in commercial sugarcane fields at six locations in the EAA. At each location, four treatments were evaluated using a randomized complete block experiment design with six replications. The insecticide treatments were phorate, ethoprop, and carbofuran. A nontreated control was also included. Wireworm population levels were higher in the nontreated control than in the phorate or carbofuran treatments. Wireworm populations were not significantly different in the ethoprop-treated sugarcane than in the nontreated control. Wireworm populations were lower in the phorate treatment than the ethoprop treatment. Wireworm populations in the carbofuran treatment were intermediate between the phorate and ethoprop treatments. Early-season and mid-season tiller populations were lower in the nontreated control than in any of the soil insecticide treatments. Sugarcane yield was lower in the nontreated control than in any of the soil insecticide treatments. Sugar yield per Mg cane was higher in the nontreated control than any of the chemical treatments. Sugar yield per ha response closely reflected the cane tonnage yield response and was lower in the nontreated control than in the soil insecticide treatments, among which there were no significant differences.

### INTRODUCTION

Sugarcane (*Saccharum* spp.) grown on Histosols (organic soils) in the Everglades Agricultural Area (EAA) is attacked by two major groups of soil insect pests: wireworms (Order Coleoptera, Family Elateridae) and white grubs (Order Coleoptera, Family Scarabaeidae) (Cherry, 1988). Several species of wireworms are present in EAA sugarcane fields including *Melanotus communis* (Gyllenhal), *Glyphonyx bimarginatus* (Schaeffer), *Orthostethus infuscatus* (Germ.), and *Conoderus* spp. (Ingram et al., 1939; Gifford, 1964; Cherry, 1988). *M. communis* is the most abundant wireworm species (Ingram et al., 1939; Cherry, 1988) and has been considered the most destructive soil insect pest of sugarcane in Florida (Gifford, 1964). Hall (1985) has reviewed the nature of damage caused by wireworms on the underground portions of the sugarcane plant and seed pieces.

Early investigations concerning the efficacy of chemical insecticides for control of wireworm populations on Florida sugarcane were conducted in the early 1950's (Ingram et al., 1951; Gifford, 1964). Since that time, the efficacy of many insecticides and cultural practices for wireworm control in the EAA has been evaluated (Walker, 1968; Genung, 1970; Samol and Johnson, 1973; Hall and Cherry, 1985). Samol and Johnson (1973) evaluated sugarcane yield response to application of three rates each of five different soil insecticides on an organic soil in the EAA. They found the nontreated control to have lower early-season tiller populations and lower millable stalk yields at harvest than any insecticide treatment. These researchers reported few significant differences in sugar yield per ha among the insecticide treatments. However, sugar yield per ha was significantly lower in the nontreated control than in any of the insecticide treatments. Unfortunately, Samol and Johnson (1973) did not collect wireworm population data or attempt to evaluate the efficacy of the insecticides tested for reducing wireworm populations.

The objective of this research was to evaluate the sugarcane yield response to soil insecticides applied at planting for wireworm control. Wireworm infestations in the EAA vary widely from year to year and by location (Ingram et al., 1938; Ingram et al., 1951; Cherry, 1988). It is important that sugarcane yield response data be collected over several field environments in order to encompass the naturally occurring spatial and temporal variability in wireworm populations.

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## MATERIALS AND METHODS

Evaluations were conducted in commercial sugarcane fields at six locations in the EAA (Table 1). At each location, four treatments were evaluated using a randomized complete block experiment design with six replications. Each plot was 6.1-m wide (4 rows), 9.1-m long and was flanked by 4 rows (6.1 m) of nontreated sugarcane. There was a 3-m wide nonplanted area at both ends of each plot. The insecticide treatments were phorate (O,O-diethyl S-[(ethylthio) methyl] phosphorodithioate) applied as Thimet<sup>®</sup> 20-G (American Cyanamid Company, Wayne, NJ), ethoprop (O-ethyl S, S-dipropyl phosphorodithioate) applied as Mocap<sup>®</sup> 20%G (Rhône-Poulenc Ag Company, Research Triangle Park, NC), and carbofuran (2,3-dihydro-2,2-dimethyl-7-benzofuranyl methylcarbamate) applied as Furadan<sup>®</sup> 15G (FMC Corporation, Philadelphia, PA). A nontreated control was also included. All insecticides were applied at 4.5 kg active ingredient/ha. A hand shaker was used to apply the dry granular materials in a 25-cm wide band covering a double-line of seed pieces in the open furrow. Furrows were closed within two hours of application. Early-season tiller populations were determined three to four months after planting and mid-season tiller counts were made six to eight months after planting by counting all tillers in the four 9.1 m rows per plot (Table 1). Wireworm larvae population density was determined in the field approximately four to five months after planting by removing soil, seed pieces, and sugarcane plants from a 2-m section (0.5-m wide, 0.25-m deep) of one of the two middle rows of each plot (Table 1). Soil, seed pieces, and plants were visually inspected for wireworms in the field. Sugarcane and sugar yields were determined between 12 and 15 months after planting (Table 1). All stalks in the four-row plot were cut by hand at the soil surface, topped at the uppermost hard node, and weighed with a tractor-mounted weighing grab loader. A 15-stalk sample was randomly collected from each plot. Each sample was weighed and crushed with a three-roller mill. Crusher juice was analyzed for Brix by laboratory refractometer and polarization after clarification with lead subacetate. Juice temperature was recorded. Theoretical sugar yield (kg sugar/Mg cane) was calculated according to Arceneaux (1935). Analysis of variance for all data was conducted using SAS PROC GLM procedures (SAS Institute, 1985).

Table 1. Characteristics of the six experiment locations in the EAA and data collection dates.

Site	Muck Soil type <sup>1</sup>	Prior crop <sup>2</sup>	Planting date	Cultivar	Wireworm population sampling date	Sugarcane tiller population		Yield harvest <sup>3</sup>
						early	mid-season	
1	Torry	SC	02-03-87	CP72-1210	05-27-87	05-06-87	08-04-87	02-25-88
2	Lauderhill	Fallow	02-09-87	CP72-1210	----	04-20-87	07-27-87	03-09-88
3	Pahokee	SC	12-28-87	CL61-620	05-23-88	04-06-88	08-23-88	02-21-89
4	Terra Ceia	SC	01-09-88	CP72-1210	06-06-88	04-27-88	08-23-88	02-18-89
5	Pahokee	SC	12-13-88	CP73-1547	----	04-06-89	----	----
6	Pahokee	Corn	01-26-89	CP70-2233	----	04-06-89	----	----

<sup>1</sup> Torry muck and Terra Ceia muck = Euic, hyperthermic Typic Medisaprists.  
Lauderhill muck and Pahokee muck = Euic, hyperthermic Lithic Medisaprists.

<sup>2</sup> SC = Experiment planted as successive plant cane.  
Fallow = Dry, weedy fallow for at least two years.  
Corn = Fall-crop hybrid seed corn (*Zea mays* L.).

<sup>3</sup> Yield harvest data not available for locations 5 and 6.

## RESULTS AND DISCUSSION

The majority of the wireworm larvae recovered at the three locations sampled were *M. communis* (65%) and *G. bimarginatus* (30%). Averaged across three locations, wireworm populations were significantly ( $P < 0.05$ ) higher in the nontreated control than in the phorate or carbofuran treatments (Table 2). Wireworm populations in the ethoprop-treated sugarcane were not significantly different from the nontreated control. Wireworm populations were lower in the phorate treatment than the ethoprop treatment. Hall and Cherry (1985) conducted contact toxicity tests under laboratory conditions with *M. communis* from which they concluded that there were no significant differences among the LD<sub>50</sub> values for technical grade acetone solutions of phorate, ethoprop, or carbofuran. Differences observed in the current field study reflect the efficacy of these materials as applied to commercial sugarcane fields.



There was a significant ( $P < 0.01$ ) treatment x location interaction affecting wireworm population (Table 2). At two of the three locations where wireworm populations were estimated (locations 3 and 4), the recovered populations were very low and there were no statistically significant differences among any of the treatments. Wireworm population samples collected earlier in the season may have provided a better assessment of larvae population levels present at planting since pupae and adults were observed in samples collected in May. Only at location 1 was the estimated population in the nontreated control above the economic injury threshold of 1.33 wireworms/m<sup>2</sup> suggested by Hall (1985). At this location, phorate and carbofuran significantly reduced the estimated wireworm populations while ethoprop did not.

Table 2. Wireworm populations as affected by soil insecticides applied at planting.

Insecticide	Overall	Location		
		1	3	4
		----- wireworms m <sup>-2</sup> -----		
Control	0.78	1.80	0.38	0.16
Phorate	0.26	0.33	0.38	0.06
Ethoprop	0.66	1.59	0.38	0.00
Carbofuran	0.44	0.71	0.38	0.22
LSD (0.05)	0.32	0.76	0.55	0.23

When averaged over all six locations, early-season tiller populations were lower in the nontreated control than in any of the soil insecticide treatments (Table 3). Phorate treated sugarcane had higher early-season tiller populations than the ethoprop treatment, while the carbofuran treatment was intermediate.

There was a significant ( $P < 0.01$ ) treatment x location interaction affecting early-season tiller population (Table 3). At location 1, there were significant differences in tiller populations among all four treatments (phorate > carbofuran > ethoprop > control). At location 2, there were no significant differences in tiller populations among the insecticide treatments or the control. At location 3, phorate allowed for more early-season tillers than the nontreated control. At location 4, the three insecticide treatments were not different but each had greater early tiller populations than the nontreated control. At location 5, phorate and ethoprop both allowed for more early-season tillers than the nontreated control. At location 6, there were no significant differences in tiller populations among the insecticide treatments or the control. The lack of early-season tiller population response to the insecticide treatments at locations 2 and 6 may be related to previous cropping history (Table 1). Fallow land management at location 2 would not have supported a large native wireworm population. Corn production in the EAA (location 6) typically involves the application of relatively high rates of soil insecticides at planting. Therefore, there probably was little soil insect pest pressure at these two locations and soil insecticides applied at the time of sugarcane planting did not elicit a response in sugarcane growth.

Early-season tiller populations were very high at location 5 (Table 3). The EAA experienced freezing temperatures on February 25 and 26, 1989 (Miller, 1990). This moderate freeze occurred ten weeks after location 5 was planted (Table 1) and killed the above ground vegetation (primary shoots) at this location. The freeze stimulated production of numerous secondary tillers, resulting in high early-season tiller populations. Location 6 was planted only four weeks prior to the February 1989 freeze (Table 1) and freezing temperatures had little effect on un-emerged shoots.

Table 3. Sugarcane tiller populations at two sampling dates as affected by soil insecticide applied at planting.

Insecticide	Early-season						
	Overall	Location					
		1	2	3	4	5	6
		-----tillers/ha-----					
Control	34,214	11,152	26,819	31,542	19,614	70,473	45,686
Phorate	44,634	45,148	29,301	39,197	25,175	88,022	40,962
Ethoprop	41,012	31,155	28,793	35,731	24,368	86,198	39,825
Carbofuran	42,920	37,135	29,481	36,477	25,474	82,341	46,613
LSD (0.05)	2,722	4,918	2,828	6,671	4,738	13,071	7,564

Insecticide	Mid-season				
	Overall	Location			
		1	2	3	4
		-----tillers/ha-----			
Control	67,154	58,842	56,927	83,090	69,754
Phorate	82,223	101,956	63,057	85,810	78,066
Ethoprop	78,882	91,521	66,645	83,270	74,090
Carbofuran	78,664	94,452	58,392	85,600	76,213
LSD (0.05)	5,002	8,690	1,609	11,356	7,524

There was a significant ( $P < 0.01$ ) treatment x location interaction affecting mid-season tiller population (Table 3). However, averaged over four locations, mid-season tiller populations were lower in the nontreated control than in any of the soil insecticide treatments (Table 3). There were no significant differences in mid-season tiller populations among the soil insecticide treatments. At location 1, all chemical insecticides promoted greater mid-season tiller populations than did the control, and the phorate treatment had more tillers than the ethoprop treatment. At location 2, the mid-season tiller population of ethoprop-treated sugarcane was greater than that of phorate-treated sugarcane. Both the ethoprop and phorate treatments had more mid-season tillers than the carbofuran treatment and the nontreated control. At location 3, there were no differences in mid-season tiller populations among the insecticide treatments or the control. At location 4, phorate allowed for more mid-season tillers than the control. Mid-season tiller populations should be indicative of millable stalk populations at crop harvest.

There was a significant ( $P < 0.01$ ) treatment x location interaction affecting sugarcane yield (Table 4). Averaged over the four locations harvested for yield, sugarcane yield response to soil insecticides directly paralleled the mid-season tiller populations. Sugarcane yield was lower in the nontreated control than in any of the soil insecticide treatments, among which there were no significant differences (Table 4). There were no significant differences ( $P > 0.05$ ) among any of the treatments in harvested stalk size which averaged 1.35 kg/stalk (data not shown). At location 1, sugarcane yield was lower in the nontreated control than in any of the soil insecticide treatments. At locations 2 and 4, there were no differences among treatments. At location 3, ethoprop-treated sugarcane produced more cane per ha than phorate or the nontreated control.



Table 4. Sugarcane and sugar yield as affected by soil insecticides applied at planting.

Insecticide	Sugarcane yield				
	Overall	Location			
		1	2	3	4
-----Mg cane/ha-----					
Control	93	83	98	107	82
Phorate	102	120	97	104	87
Ethoprop	103	112	98	118	83
Carbofuran	102	117	96	110	84
LSD (0.05)	5	11	9	11	9

		Sugar Mg <sup>-1</sup> cane			
Insecticide	Overall	Location			
		1	2	3	4
-----kg sugar/Mg cane-----					
Control	133	141	120	147	123
Phorate	131	142	118	143	121
Ethoprop	130	142	118	141	120
Carbofuran	131	137	117	146	122
LSD (0.05)	2	5	4	6	4

Insecticide	Sugar yield				
	Overall	Location			
		1	2	3	4
-----Mg sugar/ha-----					
Control	12.4	11.7	11.8	15.7	10.1
Phorate	13.4	17.0	11.4	14.9	10.5
Ethoprop	13.4	15.9	11.6	16.6	10.0
Carbofuran	13.4	16.0	11.2	16.1	10.2
LSD (0.05)	0.7	1.8	1.0	1.4	1.2

There was a negative correlation between wireworm population and sugarcane yield at location 1:

Mg cane/ha =  $122 - 12.4(\text{wireworms/m}^2)$ ,  $r^2 = .41$ ,  $P < 0.001$ .

Similar significant correlations did not exist for locations 3 or 4 or the average of the three locations.

Overall, sugar yield per Mg cane was higher in the nontreated control than in any of the chemical treatments (Table 4). Again, there was a significant ( $P < 0.01$ ) treatment x location interaction affecting sugar yield per Mg cane (Table 4). At location 1, carbofuran-treated sugarcane produced less sugar per Mg cane than phorate or ethoprop. At location 3, the ethoprop treatment produced less sugar per Mg cane than the nontreated control. At locations 2 and 4, there were no differences among any treatments.

Sugar yield per ha response to soil insecticides closely reflected the cane tonnage yield response. Sugar yield per ha was lower in the nontreated control than in any of the soil insecticide treatments, among which there were

no significant differences (Table 4). Also, there was a similar significant ( $P < 0.01$ ) treatment x location interaction affecting sugar yield per ha (Table 4).

The data indicate that sugarcane yield response to soil insecticides in the EAA is highly variable among locations. When a soil insecticide was applied at planting, sugar yield per ha was approximately 10 percent higher than when soil insecticides were omitted. On the average, each of the three soil insecticide treatments evaluated in this study had similar affects on sugar yield.

#### ACKNOWLEDGEMENTS

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## EFFECTS OF WATER-TABLE DEPTH ON WATER RELATIONS AND YIELD FOR SUGARCANE GROWN IN SAND

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### ABSTRACT

The objectives of the study were to determine the influence of depth to the water-table on water relations, cane and sugar yield. Sugarcane (*Saccharum*, cv. CP 72-1210) was grown on Malabar fine sand (Grossarenic Ochraqualf) for two seasons under two water-table levels: a higher water-table (HWT) of 35-50 cm and a lower water-table (LWT) of about 75-90 cm from the soil surface. Differences in soil-water potential, leaf temperature, plant height, total cane and sugar yield between the two water-table levels were observed. Total millable stalk weights averaged for the two seasons were 102 Mg ha<sup>-1</sup> and 93 Mg ha<sup>-1</sup> for the HWT and LWT treatments, respectively.

### INTRODUCTION

During the past two decades sugarcane production has been expanding in south Florida at the rate of approximately 4,000 ha yr<sup>-1</sup>. Currently, over 175,000 ha of sugarcane are grown in the region (Coale and Glaz, 1988). The majority (90 percent) of sugarcane in Florida is grown on the organic soils of the Everglades Agricultural Area (EAA). Due to urban encroachment, soil subsidence, and environmental concerns, the production of sugarcane on the sands surrounding the EAA has increased in recent years.

The traditional irrigation practice for sugarcane in Florida is sub-irrigation (seepage), in which an elevated water table is maintained by a network of lateral-field ditches and larger field canals. For organic soils, it is desirable to maintain a relatively high water table in order to reduce soil oxidation. In many cases, this practice has been transferred to the sandy soils; however, there are insufficient data on the effects of various water-table depths on sugarcane grown in sand to insure that a high water-table is necessary for the optimum production of sugarcane on sand.

Crop yield is often affected by water-table levels. In most of the reported studies, sugarcane yield has been greater with lower water-table depths (Carter, et al., 1988 and 1985; Shih and Gascho, 1980; and Carter and Floyd, 1975). However, both of these studies were on fine textured soils. Field observations in Florida on sand have been rather contradictory. Many growers claim that greater yields result from a higher water table. Since a majority of the crop evapotranspiration (ET) requirements under seepage irrigation are met by capillary rise from the water table, it is necessary to have the water table close enough to the root zone to allow for sufficient upward flux to meet the ET requirement. Due to large pore diameters in sandy soils, there is often limited capillary rise. Therefore, it is a common practice on many crops grown in southern Florida to maintain a moderately high (30 - 45 cm from the soil surface) water table. Optimum water-table depth is likely to be affected by soil texture and rooting characteristics of the plant.

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<sup>1</sup>SWFREC is the Southwest Florida Research and Education Center



Yields of sugarcane grown on sand in Florida are generally less than those grown on the organic soils (Anderson, 1990). The low water-holding capacity of these soils may make water-table management more critical. Currently, information from Florida on the effects of water-table level on the relationship between soil-water status and sugarcane plant-water relations on sandy soil is limited.

Water-table level is also important in determining the amount of water pumped for seepage irrigation. The depth of the water table has an effect on the quantity of pumpage for irrigation and on the effectiveness of rainfall. Effective rainfall can be defined as rainfall that is stored in the root zone and therefore is available to the plant to meet ET requirements. Effective rainfall is directly related to the water-table depth (Shih and Gascho, 1980). With a lower water table, more soil volume is available to store rainfall. Thus, a lower water table reduces pumping requirements for drainage and irrigation and could potentially decrease the magnitude of off-site discharge.

Tensiometers (Richards and Weaver, 1944) have been used for many years for monitoring soil-water status. Soil-water potential (SWP), the sum of matric and osmotic potentials, is a useful index for characterizing the energy status of soil water with respect to plant water uptake (Hillel, 1982). However, on sand the majority of the available soil water is held through a very small range of SWP.

Canopy temperature has been shown to be a useful parameter in describing plant-water status for many crops (Idso et al., 1982). The relationship between canopy temperature minus ambient temperature ( $T_c - T_a$ ) and vapor pressure deficit (VPD) is an indicator of plant-water stress. The VPD is defined as the difference between the partial pressure of water vapor in the atmosphere to the partial pressure of water vapor in a saturated environment at that same temperature. Transpiration rates are controlled by stomatal aperture and evaporative demand. As the plant-water deficit increases, stomatal conductance declines and ( $T_c - T_a$ ) will tend to increase. This increase can be assessed by infrared thermometry (Reginato, 1983).

The objectives of this study were to determine the influence of depth to the water table on soil-water and plant-water relations, cane and sugar yield for sugarcane grown on sandy soil.

## MATERIALS AND METHODS

The field study was conducted at the Southwest Florida Research and Education Center (SWFREC) near Immokalee, Florida. The soil was predominately a Malabar fine sand (Grossarenic Ochraqualf) which is 98% sand and has an argillic horizon at about 1 m from the soil surface (Yamataki, 1988). The experimental site was approximately 1.6 ha. A 1.25-m deep rim ditch was constructed around the site to control the movement of surface and ground water. Eight experimental plots 15.3 by 15.3 m were constructed with a 1-m deep ditch surrounding each plot. Plots were separated by 15.3 m wide buffer areas. Water was pumped to each plot ditch through underground pipes and discharged into the plot ditch through a float-actuated valve. In each plot, a float-actuated sump pump was installed to remove water when the ditch water level was greater than the target level. The experiment was a randomized complete block design with four replications. The water level treatments were: 1) high water-table (HWT) at 35-50 cm and 2) low water-table (LWT) at 75-90 cm.

Sugarcane (*Saccharum* spp., cultivar CP 72-1210) was hand-planted in Jan 1988 in rows 1.5 m (5 ft.) apart in accordance with standard grower practice. Seed-cane pieces were approximately 40 cm long with 3 to 4 nodes per seed piece. In the second year a ratoon crop was grown. Fertilizer was applied in the furrow before planting. Additional fertilizer was applied in the first year with three split applications on approximately 15 Apr, 1 Jun and 15 Jul. This same regime was followed in the second year. Total annual fertilizer applications each year were 225 kg N ha<sup>-1</sup>, 50 kg P ha<sup>-1</sup>, and 230 kg K ha<sup>-1</sup>. Weeds were controlled with hand cultivation and herbicides.

Water-table observation wells were placed approximately half-way between the plot center and the ditch center. Ditch-water levels and water-table levels within the plots were monitored three times each week (MWF) by site gages and observation wells. A continuous record of water level was maintained with a water-stage recorder in one plot of each treatment. Tensiometers were placed at 15-cm and 30-cm depths next to the observation wells within each treatment to measure SWP.

Following a period of several weeks without significant rainfall, soil-water content was measured gravimetrically in two of the LWT plots. Six samples each from five depths were removed at each location and oven dried at 105 °C. Mass water content was converted to volumetric water content by assuming a soil bulk density of 1.3 g cm<sup>-3</sup> (Obreza, 1990).



Canopy temperature ( $T_c$ ) and air temperature ( $T_a$ ) along with the vapor pressure deficit (VPD) were measured between 1100 and 1400 hrs. The instrument (Scheduler) used to obtain the data was equipped with an infrared sensing devise and means of measuring VPD and ambient temperature. Data were obtained following several weeks in which there was not significant rainfall, thus the water table was the primary water source for meeting the crop's ET demand.

Plant height measurements and tiller population counts were made monthly from two randomly selected 3-m lengths of row in each plot. Cane and sugar yields were determined in January of each year by hand harvesting at two 3 m lengths of plant row in each plot. Sucrose and sugar yield were determined by laboratory analysis (Anderson, 1990). Data were compared using standard procedures for analysis of variance (SAS).

## RESULTS

Both years, 1988 and 1989 were drier than normal. Rainfall totaled 97 cm in 1988 and 123 cm in 1989. Based on a 30-year record, normal annual rainfall at the site is 133 cm. The combined rainfall deficit for the two years was 46 cm. Rainfall distribution through the year resulted in the majority of the precipitation occurring in the summer months (Jun-Sep). Rainfall events with a magnitude of 5.0 cm or more occurred once in 1988 and seven times in 1989.

Due in part to the drought conditions, ditch-water levels were consistently higher (approximately 20-30 cm) than plot-water levels at the observation wells. Fig. 1 gives the average observed plot-water level for both treatments in 1988. Ditch water levels varied less than did plot-water levels. This same relationship was observed in 1989.

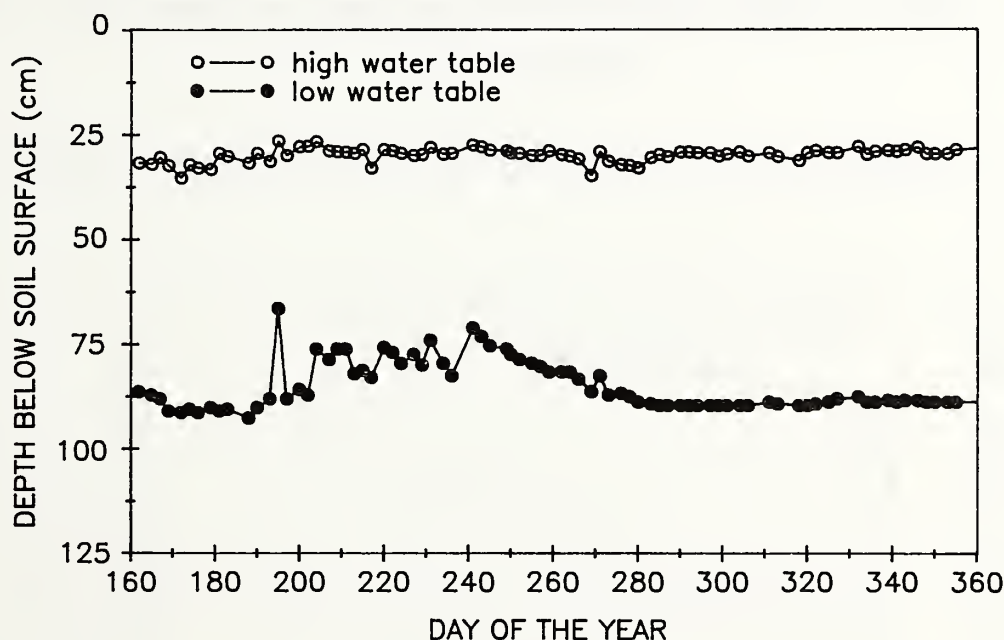


Figure 1. Average plot water levels in high and low water table and treatments.

The tensiometer record of SWP for the HWT and LWT treatments at the 30 cm depth is shown in Fig. 2. These data indicate considerable upward flux from the water table. A laboratory determined moisture-release curve for a Malabar fine sand is shown in Fig. 3 (Carlisle et al., 1989). Soil water content from gravimetric sampling is given in Table 1. These data indicate moist conditions corresponding to SWP greater than -10 kPa.

<sup>2</sup> Scheduler is a trademark name of Standard Oil Engineering Materials Company; the use of the trade name does not imply endorsement by the authors.

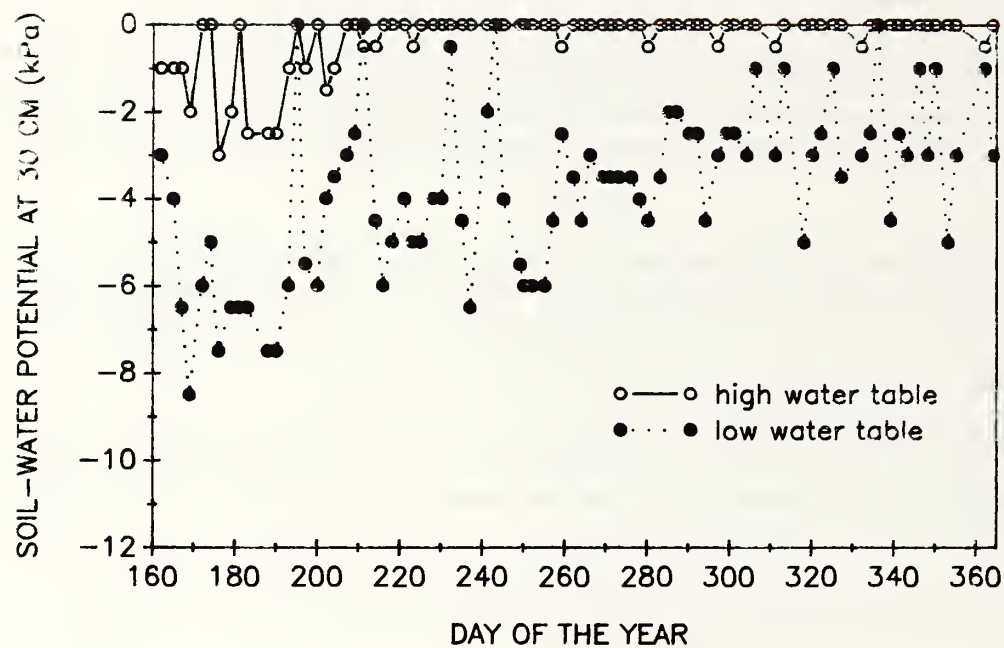


Figure 2. Average SWP at the 30 cm soil depth in the high and low water table and treatments.

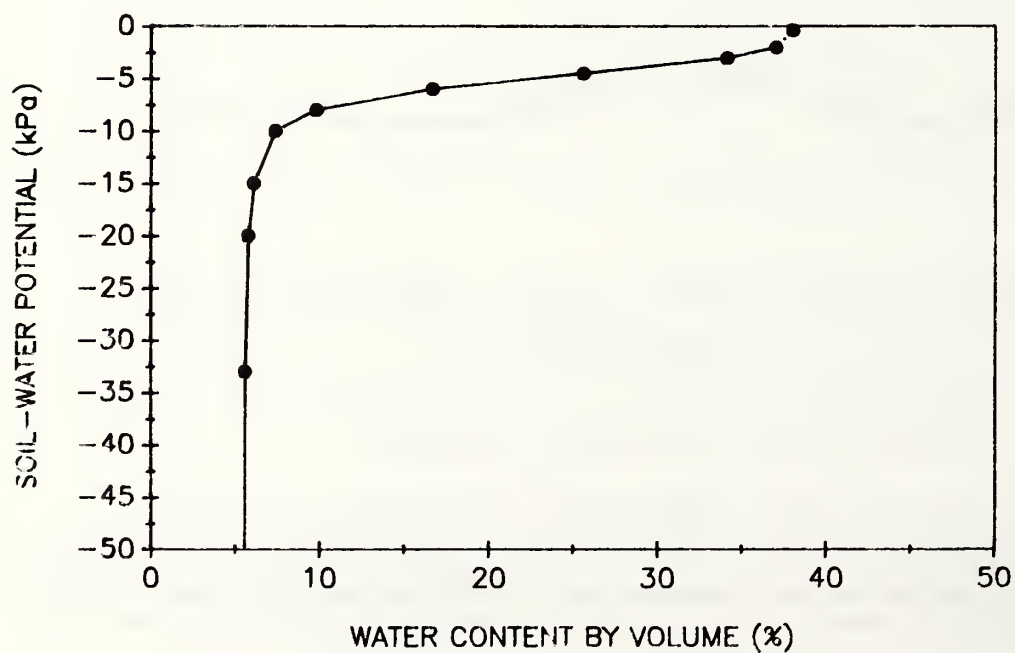


Figure 3. Moisture release curve for Malabar fine sand (Carlisle, V.W., et al., 1989).

Table 1. Soil water content (%) by volume as a function of depth in LWT treatment.

Depth	(cm)	0-15	15-30	30-45	45-60	60-75
H <sub>2</sub> O	(%)	9.9	12.7	18.6	23.5	27.1

Due to drought conditions and the slightly different soil type within one of the plots, it was not possible (with the water supply system) to maintain the treatment water level in that plot during a three-week period in May and June of 1989. Water levels in that individual plot fell to as low as 130 cm from the soil surface. At that time this plot was used to measure canopy temperature under water-stressed conditions. Yield and plant growth data for 1989 from that plot were omitted from the final analysis; it was much lower than all other plots.

Data comparing ( $T_c - T_a$ ) vs. VPD from the HWT treatment are shown in Fig. 4. Each data point represents at least 30 samples taken at a very close interval of time. The determination coefficient ( $r^2 = 0.86$ ) indicates a highly linear relationship, which is consistent with data reported for other crops (Howell et al., 1984). Since these measurements were made under a well-watered condition, based on SWP as measured by tensiometers, it could be considered the unstressed baseline for the development of a crop water stress index (CWSI) for sugarcane. Similarly, shown in Fig. 5 is the same comparison for the LWT. The small change in slope between the two treatments is a possible indication of minor water stress. Shown in Fig. 6 is temperature and VPD data from the water-stressed plot. The shift upward is quite clear; water stress is represented by the relatively flat slope of only -0.53.

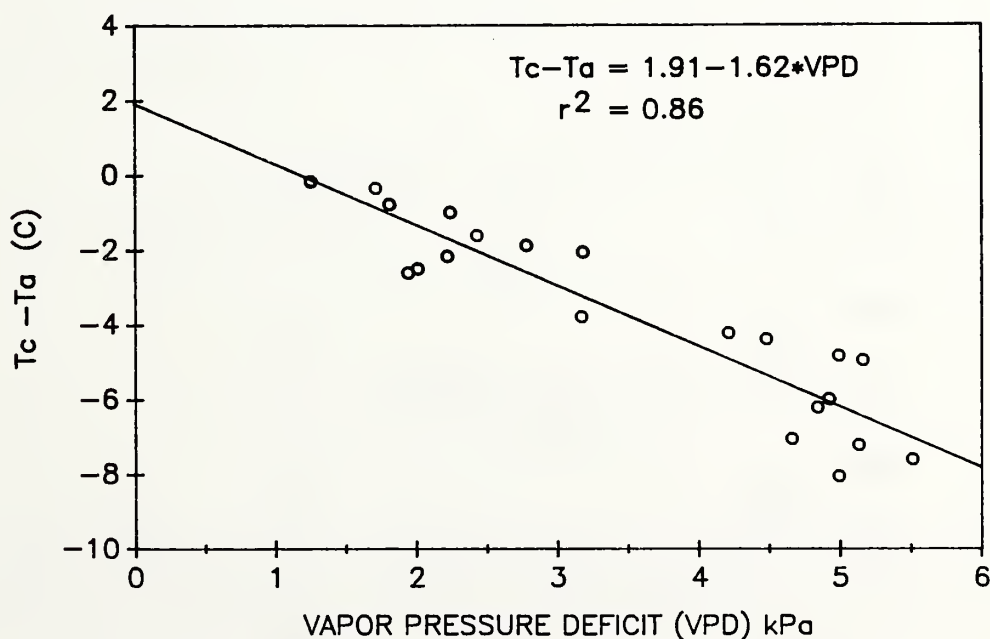


Figure 4. Canopy temperature minus ambient temperature verses vapor pressure deficit for the high water table treatment.

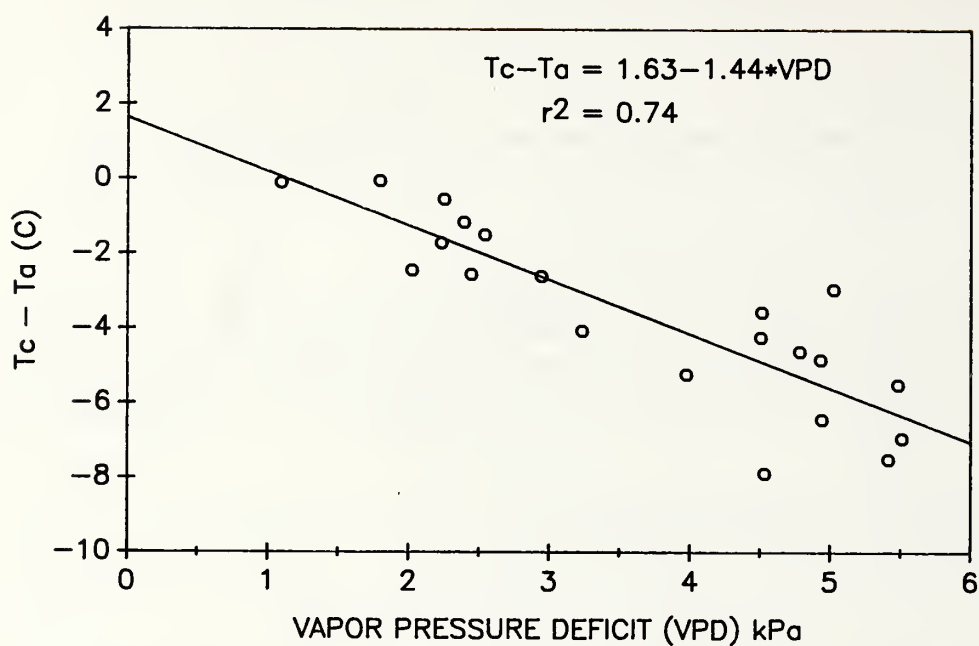


Figure 5. Canopy temperature minus ambient temperature verses vapor pressure deficit for the low water table treatment.

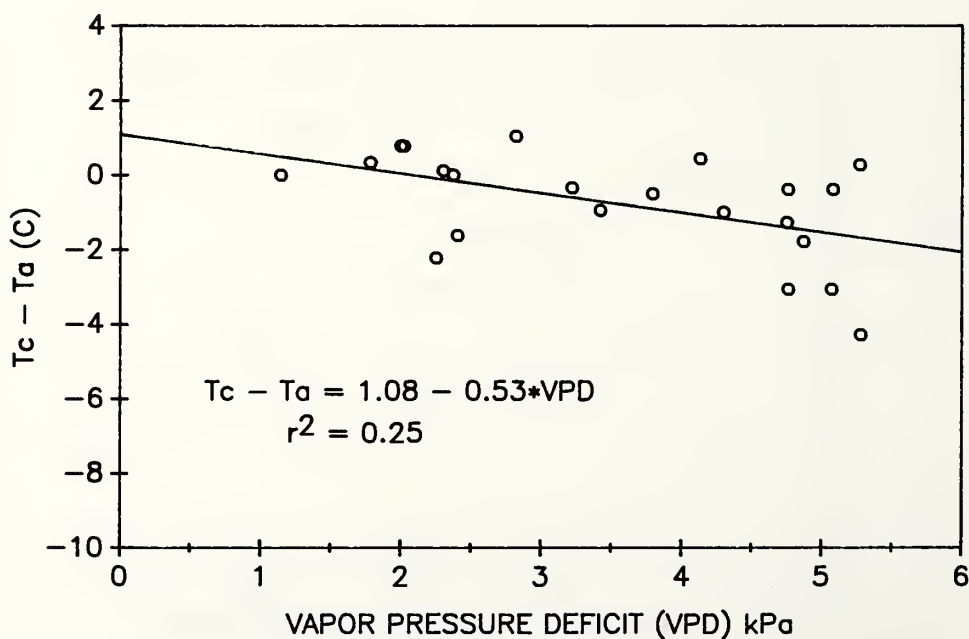


Figure 6. Canopy temperature minus ambient temperature verses vapor pressure deficit for the water table treatment.



Tiller population reached a peak of approximately 160,000 tiller ha<sup>-1</sup> in July 1988 and in May 1989. Tiller populations declined from that peak and leveled off at about 80,000 ha<sup>-1</sup> by October. There was no significant difference in tiller counts between the two treatments. Plant height was affected by water-table depth. In 1988 HWT had greater height through the summer months, however, by harvest no difference in plant height was observed. In 1989 HWT plant height was approximately 10 % greater than that of the LWT treatment (Fig. 7).

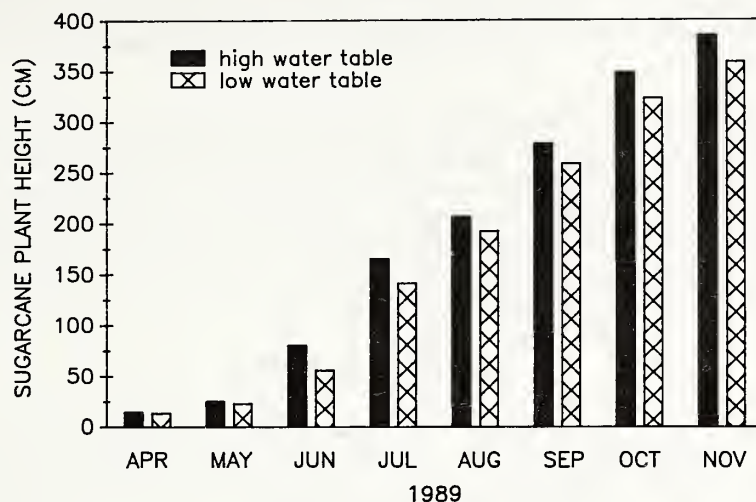


Figure 7. Plant Height (cm) in high and low water table treatment.

A summary of yield data is given in Table 2. Total millable stalk weight averaged for the two seasons 102 Mg ha<sup>-1</sup> and 93 Mg ha<sup>-1</sup> for the HWT and LWT treatments, respectively. Sugar yields were reduced by more than 1 Mg ha<sup>-1</sup> with the lower water table. These yield differences were statistically significant ( $P < 0.05$ ). This represented a 9 percent yield reduction due to lowering the water-table from a HWT (35-50 cm) to a LWT (75-90 cm).

Table 2. Summary of sugarcane yield.<sup>1</sup>

Treatment	Sugarcane (Mg ha <sup>-1</sup> )	Sugar (Mg ha <sup>-1</sup> )
(1988)		
HWT	100	13.8
LWT	92	12.9
(1989)		
HWT	104	12.6
LWT	94	10.8
(2-season Average)		
HWT	102a <sup>2</sup>	13.2c
LWT	93b	11.9d

<sup>1</sup> Mg ha<sup>-1</sup> = (0.445 ton ac<sup>-1</sup>).

<sup>2</sup> Means with different letters are significantly different at the 0.05 % level.

## DISCUSSION

Very high SWP values were measured for both the HWT and the LWT treatments. These moisture conditions were substantiated by the high soil-water content determined by gravimetric sampling. This indicated significant upward movement of water by capillary forces in Malabar fine sand.

Data and analysis from this study indicate that the  $(T_c - T_a)$  vs. VPD relationship can be a sensitive indicator of sugarcane water stress. The drawback to the practical use of this instrument is that it is quite sensitive to interference due to cloud cover and is affected by changing windspeed, both of which are common conditions in south Florida.

Although both treatments were seemingly 'well-watered' and there was only a very small difference observed in the slope of the  $(T_c - T_a)$  vs. VPD regression equation between the two treatments, yield was affected. The higher water table seemed to provide better irrigation on sandy soil than the lower water table. These results are contrary to results reported on fine textured soils. The coarser textured sandy soils perhaps allow greater  $O_2$  diffusion rates. Another explanation is that the drought tolerance of sugarcane is cultivar dependent. The cultivar used in this study (CP-72-1210) was developed under very moist conditions common in the organic soils of the EAA and may have a genetic preference to wet-soil conditions.

## ACKNOWLEDGMENTS

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## PHENOTYPIC CHARACTERISTICS OF F<sub>2</sub> AND BC<sub>1</sub> PROGENIES FROM SUGARCANE INTERGENERIC CROSSES

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### ABSTRACT

Genera related to sugarcane have many desirable traits that can be used to improve sugarcane yield and adaptability to environments. Genetic data on the economically important traits can serve as a guide to enhance germplasm utilization and to improve efficiency of current breeding methodology. The objectives of this study were to examine the genetic behavior of morphological and juice quality traits in the F<sub>2</sub> and BC<sub>1</sub> generations and to estimate the change in these traits after the first round of genetic recombination through backcrosses or self pollination. The F<sub>2</sub> and BC<sub>1</sub> seedlings from intergeneric crosses of sugarcane x *Miscanthus* sp., sugarcane x *Miscanthidium* sp., and sugarcane x *Erianthus* sp. were evaluated for stalk diameter, fiber content, Brix, sucrose content and purity. Mean sucrose content of F<sub>2</sub> and BC<sub>1</sub> progenies was markedly improved over that in the F<sub>1</sub> hybrids, but mean stalk diameter was still very small. However, Brix and percent purity were improved by nearly two-fold. The F<sub>2</sub> and BC<sub>1</sub> progenies gave a wide range of continuous variation for all five traits. Differences in the coefficients of variation between generations indicate that the genetic variability in F<sub>2</sub> and BC<sub>1</sub> progenies was slightly greater than in F<sub>1</sub> progenies. Juice quality of F<sub>2</sub> and BC<sub>1</sub> progenies was improved greatly; therefore, selection for high juice quality should be effective in these populations. These results suggest that the improvement in stalk diameter will require additional backcrosses.

### INTRODUCTION

In an earlier publication, Tai and Miller (15) briefly reviewed reasons for using genera related to *Saccharum* in sugarcane breeding. These included expansion of the germplasm base of commercial sugarcane and breeding clones, transfer of desirable characteristics that do not exist in a satisfactory degree in *Saccharum*, the heterotic effect for yield and sugar content, and the establishment of genetic information necessary to continue yield increases through genetic manipulation. In order to more effectively use intergeneric hybridization in sugarcane, information on the genetic behavior of characters of economic importance needs to be established.

Several inheritance studies of various characters of intergeneric hybrids between *Saccharum* and related genera have been published (2,7,12,15). Tai and Miller (15) studied stalk diameter, Brix, percent sucrose and percent purity in the F<sub>1</sub> seedling populations from crosses between commercial sugarcane cultivars and *Erianthus* and *Miscanthus*. They found great variation in those characters. Chen (2) conducted a detailed genetic analysis of morphological characters of a single hybrid plant obtained from a cross between POJ 2725 (an interspecific hybrid sugarcane cultivar) and *Miscanthus japonicus* (this species has since been renamed as *M. floridulus*). The intergeneric hybrid is an OMM type, which resulted from fertilization of a reduced gamete (O genome) of POJ 2725 by an unreduced gamete (MM genomes) of *M. floridulus*. Based on phenotypic expression, there was evidence of dominance, recessiveness, additive (dosages), and epistatic effects of genes of *M. floridulus*, among the characters that were studied. Chen et al. (3) used a composite population derived from sugarcane x *Miscanthus* hybrids, which consisted of a group of selected clones from crosses between commercial sugarcane cultivars and two *Miscanthus* species (*M. sinensis* and *M. floridulus*), to examine the performance of some important agronomic characters. They reported that tillering, stalk diameter, pithiness, and sucrose content were intermediate between two parents. Genes conferring downy mildew resistance and improved ratooning ability were dominant. Chromosome numbers of sugarcane x *Miscanthus* F<sub>1</sub> hybrids ranging from 2n = 70 to 100 showed irregular meiosis. Lo et al. (8) also used the same F<sub>1</sub> hybrids to produce BC<sub>1</sub>, BC<sub>2</sub> and BC<sub>3</sub> progenies in an attempt to transfer the desirable genes conferring disease resistance, ratooning ability, and yield performance from *Miscanthus* to cultivated sugarcane. A critical inheritance analysis of those characters was not conducted and would not be meaningful due to the mixed nature of the population. Furthermore, the possibility that *M. sinensis* and *M. floridulus* have dissimilar gene action when crossed with commercial sugarcane cultivars was not discussed. In a more recent report, Lo and Chen (9) established a regression model which indicated that improvement in sugar content of *Saccharum* x *Miscanthus* hybrids was significant and constant as nobilization generations advanced, but the increase in sugar content was greater in more advanced generations (BC<sub>3</sub> and BC<sub>4</sub>) than in early generations (F<sub>1</sub> and BC<sub>1</sub>) during the nobilization process.



Objectives of this study were to determine the segregation characteristics of morphological characters and juice quality traits in the  $F_2$  and  $BC_1$  generations of crosses between interspecific hybrid sugarcane cultivars and related genera, and to measure the change in these traits after the first round of genetic recombination through backcrosses or self-fertilization.

## MATERIALS AND METHODS

During the 1987/88 flowering season,  $F_1$  hybrids from crosses between two interspecific hybrid sugarcane cultivars (CP 65-357 and NCo 310) and three genera related to *Saccharum* (*Erianthus*, *Miscanthus* and *Miscanthidium*) (Table 1) were used as parental clones to produce  $F_2$  seed by self-pollination and  $BC_1$  seed by backcrossing them to other commercial sugarcane cultivars or to a noble (*Saccharum officinarum*).

Table 1. List of  $F_1$ ,  $F_2$  and  $BC_1$  families used in the genetic analysis of intergeneric hybridization between sugarcane and its related genera

$F_1$ , 1985/86	$F_2$ or $BC_1$ , 1987/88	$F_2$ or $BC_1$ , 1988/89
Interspecific hybrid sugarcane cultivar 'CP 65-357' x <i>Erianthus arundinaceus</i> 'IS 76-178'	$F_2$ :US 87-1016 ( $F_1$ ) [= $F_1$ (CP-65-357 x IS 76-178)] selfed	$F_2$ :US 87-1016 ( $F_1$ ) [= $F_1$ (CP 65-357 x IS 76-178)] selfed
Interspecific hybrid sugarcane cultivar 'NCo310' x <i>Miscanthus sinensis</i> 'PI 3905'		$F_2$ :US 87-1018 ( $F_1$ ) [= $F_1$ (NCo 310 x PI 3905)] selfed $BC_1$ :US 87-1018( $F_1$ )x CP 83-1281
Interspecific hybrid sugarcane cultivar 'NCo310' x <i>Miscanthus sinensis</i> 'PI 3905'		$F_2$ :US 87-1019 ( $F_1$ ) [= $F_1$ (NCo 310 x PI 3905)] selfed $BC_1$ :US 87-1019( $F_1$ )x CP 85-830 $BC_1$ :US 87-1019( $F_1$ )x CP 83-1969
Interspecific hybrid sugarcane cultivar 'NCo 310' x <i>Miscanthus sinensis</i> 'US 47-11'		$F_2$ :US 87-1020( $F_1$ ) [= $F_1$ (NCo 310 x US 47-11)] selfed $BC_1$ :US 87-1020( $F_1$ )x CP 82-2043
Interspecific hybrid sugarcane cultivar 'NCo 310' x <i>Miscanthus sinensis</i> 'US 47-11'		$F_2$ :US 87-1021( $F_1$ ) [= $F_1$ (NCo 310 x US 47-11)] selfed $BC_1$ :US 87-1021( $F_1$ )xCP 83-1773 $BC_1$ :US 87-1021( $F_1$ )xCP 82 2043

Table 1. Continued

F <sub>1</sub> , 1985/86	F <sub>2</sub> or BC <sub>1</sub> , 1987/88	F <sub>2</sub> or BC <sub>1</sub> , 1988/89
Interspecific hybrid sugarcane cultivar 'NCo 310' x <i>Miscanthus</i> <i>floridulus</i> 'US 56-22-3'		F <sub>2</sub> :US 87-1024(F <sub>1</sub> )[ = F <sub>1</sub> (NCo-310 x US 56-22-3)] selfed
Interspecific hybrid sugarcane cultivar 'NCo310' x <i>Miscanthus</i> <i>floridulus</i> 'US 56-22-3'		F <sub>2</sub> :US 87-1025(F <sub>1</sub> )[ = F <sub>1</sub> (NCo-310 x US 56-22-3)] selfed  BC <sub>1</sub> :US 87-1025(F <sub>1</sub> )x CP 821505
Interspecific hybrid sugarcane cultivar 'NCo310' x <i>Miscanthidium</i> <i>sorghum</i> 'US 56-42-3'*	BC <sub>1</sub> :US 87-1022(F <sub>1</sub> )[ = F <sub>1</sub> (NCo 310 x US 56-42-3)] x CP 76-331 BC <sub>1</sub> :US 87-1022(F <sub>1</sub> ) x <i>Saccharum officinarum</i> 'Sylva'  BC <sub>1</sub> :US 87-1022(F <sub>1</sub> ) x CP 68-350	F <sub>2</sub> :US 87-1022 (F <sub>1</sub> ) selfed  BC <sub>1</sub> :US 87-1022 (F <sub>1</sub> ) x CP 81-1425
Interspecific hybrid sugarcane cultivar 'NCo310' x <i>Miscanthidium</i> <i>sorghum</i> 'US 56-42-3'		F <sub>2</sub> :US 87-1023(F <sub>1</sub> )[ = F <sub>1</sub> (NCo-310 x US 56-42-3)] selfed  BC <sub>1</sub> :US 87-1023(F <sub>1</sub> ) x CP 83-1281

\* *Miscanthidium sorghum* 'US 56-42-3' was previously named *Miscanthus violaceum* in an earlier report (15).

Most F<sub>1</sub> hybrids did not flower under natural field conditions, thus only one F<sub>2</sub> and three BC<sub>1</sub> seedling populations were available for this study. The F<sub>2</sub> and BC<sub>1</sub> seedlings were transplanted to field plots in a randomized complete block design with 15 replications in June 1988. Five seedlings from each of the F<sub>2</sub> and BC<sub>1</sub> families were planted as a single row plot at 0.3m intervals and with 1.5m between plots. Two sugarcane cultivars, CP 65-357 and NCo-310, were used as checks. Each block contained 7 plots. The stalk diameter was measured on five mature stalks per seedling, at mid-internode, approximately 0.5m above ground. Five to ten mature stalks from each of three random seedlings per plot were cut for milling and juice analysis in January 1989. Stalks were macerated with a Jeffco Cutter-Grinder 1/ (6). Two subsamples of approximately 120 grams each were taken from macerated samples to determine fiber percentage. The remaining sample was pressed to obtain the juice used to measure quality which included Brix, percent sucrose, and percent purity. For fiber determination, macerated samples were placed in cloth bags washed in an automatic washing machine, and dried to constant weight at 105°C (6). Fiber percentage was calculated from the fresh sample weight and the dry sample weight.

To further examine the characteristics of F<sub>2</sub> and BC<sub>1</sub> populations, F<sub>1</sub> hybrids were again used as parents in the 1988/89 flowering season to produce F<sub>2</sub> and BC<sub>1</sub> seed (Table 1). Some F<sub>1</sub> hybrids were grown under photoperiod treatment to induce flowering and the rest were grown under natural field conditions and then moved into the crossing house during the flowering time to ensure F<sub>2</sub> and BC<sub>1</sub> seed could be obtained. The F<sub>1</sub> tassels used as female parents in backcrosses were cut from cans kept in a field where the tassels would

1/. Mention of a trademark, vendor, or proprietary product does not constitute a guarantee or warranty of the product by the USDA and does not imply its approval to the exclusion of other products or vendors that may also be suitable.

be male-sterile because of exposure to low night temperatures (5). Also, some of the male-fertile  $F_1$  tassels (US 87-1018, US 87-1019, and US 87-1023) were treated with hot water (at 49°C for 10 minutes) to emasculate them (4) and were then pollinated by commercial sugarcane cultivars to produce  $BC_1$  seed. The  $F_2$  and  $BC_1$  seedlings were planted along with the regular seedling program as a nobilization project in May 1989. The seedlings were planted at 0.3m intervals and with 1.5m between rows. A total of 100 seedlings from each  $F_2$  and  $BC_1$  family were randomly selected for the measurement of stalk diameter in November. The method described previously was used to measure stalk diameter.

The analyses of variance were carried out separately for 1988/89 and 1989/90 experiments (14). Duncan's New Multiple Range Test (14) was used to compare the difference of means among  $F_2$  and  $BC_1$  families. Coefficient of variation or variability was obtained from the sample standard deviation expressed as a percentage of the sample mean in the  $F_1$ ,  $F_2$  and  $BC_1$  generations for each cross.

## RESULTS AND DISCUSSION

The results from the 1988/89 experiment showed that there were no significant differences among  $F_2$  and  $BC_1$  family means in percent sucrose, percent purity and fiber content (Table 2). There were significant differences in Brix and stalk diameter among means in the  $F_2$  and  $BC_1$  generations. The  $F_2$  seedlings derived from US 87-1016 ( $F_1$ ) self-pollination and the  $BC_1$  seedlings of US 87-1022 ( $F_1$ ) x CP 76-331 had a significantly higher Brix and larger stalk diameter than did the other two  $BC_1$  seedling families. The interspecific hybrid sugarcane cultivar, CP 76-331, contributed more toward improved Brix and stalk diameter in the first backcross than did *S. officinarum* 'Sylva'.

Table 2. Means of characters studied of  $F_2$  and  $BC_1$  generations in crosses between *Saccharum* and its related genera grown in 1988/89.

Cross	Generation	Brix (°)	Sucrose (%)	Purity (%)	Fiber Content (%)	Stalk Diameter (mm)
US 87-1016 ( $F_1$ ) selfed	$F_2$	16.65a*	12.11a	72.30a	15.59a	18.25a
US 87-1022 ( $F_1$ ) x CP 76-331	$BC_1$	15.80a	12.01a	75.69a	15.43a	17.25a
US 87-1022 ( $F_1$ ) <i>S.officinarum</i> 'Sylva'	$BC_1$	13.70b	10.14a	73.68a	15.20a	15.00b
US 87-1022 ( $F_1$ ) CP 68-350	$BC_1$	14.35b	10.32a	71.03a	15.89a	15.00b

\* Means within a column followed by the same letter were not significantly different at the 5.0% level.

A commercial cultivar, CP 65-357, was used as a standard to measure the change of the traits studied through backcross or self-fertilization in each of the five traits (Table 3). In the  $F_1$  generation the mean for each of the five traits was approximately half (50%) of the standard, which was assumed to be the target values expressed as percentage of 100% (15). Both Brix and percent purity improved markedly from  $F_1$  to the  $F_2$  or  $BC_1$  generation, but the change of percent sucrose was much less. Fiber content varied greatly among  $F_2$  and  $BC_1$  families. There was no significant increase in stalk diameter from the  $F_1$  to the  $F_2$  or  $BC_1$  generation.

Brix was obtained using an automatic refractometer. Percent sucrose was calculated from the polarization reading by using Schmitz table (10). Percent purity was calculated as the ratio of percent sucrose to Brix. Plot means were used for the analysis of variance.



Table 3. Comparison with five characters of the standard check, CP 65-357 of F<sub>1</sub>, F<sub>2</sub> and BC<sub>1</sub> generations in crosses between *Saccharum* and its related genera.

Cross	Generation	Brix (%)	Sucrose (%)	Purity (%)	Fiber Content	Stalk Diameter
CP 65-357	Standard	100.00	100.00	100.00	100.00	100.00
CP 65-357x IS 76-1	F <sub>1</sub> *	58.26	36.91	63.30	---	58.62
NCo 310 x US 56-42-3	F <sub>1</sub> *	48.89	23.34	47.1	---	53.28
US 87-1016(F <sub>1</sub> ) selfed	F <sub>2</sub>	83.26	68.52	82.66	105.14	61.23
US 87-1022(F <sub>1</sub> ) x CP 76-331	BC <sub>1</sub>	82.05	70.72	86.61	109.51	59.03
US 87-1022(F <sub>1</sub> ) x <i>S.officinarum</i> 'Sylva'	BC <sub>1</sub>	73.78	59.81	81.68	115.00	46.10
US 87-1022(F <sub>1</sub> ) x CP 68-350	BC <sub>1</sub>	79.02	65.11	82.14	115.22	51.72

\* Standard, CP 65-357, and F<sub>1</sub> seedlings were grown in the 1986/87. The measurements of CP 65-357, which were assumed to be the target values, were Brix 18.16°, sucrose 15.85%, purity 86.49%, fiber content 13.8% and stalk diameter 29.00mm.

Stalk diameter and Brix are the most repeatable and important traits used as selection criteria in early selection stages of the sugarcane variety improvement program (11,16). The segregation pattern for stalk diameter and percent sucrose were chosen for further examination in the F<sub>2</sub> and BC<sub>1</sub> generations. The frequency distribution for stalk diameter of F<sub>2</sub> and BC<sub>1</sub> generations in crosses between *Saccharum* and its relatives showed continuous variation (Table 4). Continuous variation was also observed in the F<sub>1</sub> (15). In most cases, the seedlings of F<sub>2</sub> and BC<sub>1</sub> generations had a wider range of variation than those in the F<sub>1</sub> generation. Percentages of the seedlings with a stalk diameter  $\geq$  19mm varied among F<sub>2</sub> and BC<sub>1</sub> families. The F<sub>2</sub> progenies from crosses between CP 65-357 and *E. arundinaceus* 'IS 76-178' and the BC<sub>1</sub> progeny from the backcross between US 87-1022 (F<sub>1</sub>) and CP 76-331 had relatively higher percentages of seedlings with stalk diameter  $\geq$  19mm (41% and 23%, respectively).

The variation of percent sucrose in the seedling populations of F<sub>2</sub> and BC<sub>1</sub> generations from a wide cross between *Saccharum* and its related genus also showed continuous variation as did in the F<sub>1</sub> (Table 5) (15). The frequency distribution of the F<sub>2</sub> seedlings derived from self-fertilization of US 87-1016 (F<sub>1</sub>) had a mode located around 10% sucrose content whereas the frequency distribution derived from US 87-1022 (F<sub>1</sub>) backcrossed to various interspecific hybrid sugarcane cultivars or *S. officinarum* had modes between 10 and 12% in sucrose content. The mean of sucrose content of either F<sub>2</sub> or BC<sub>1</sub> was greater than that of its respective F<sub>1</sub> population, but the coefficients of variability of both F<sub>2</sub> and BC<sub>1</sub> were less than that of the F<sub>1</sub> except for the BC<sub>1</sub> population of US 87-1022 (F<sub>1</sub>) x CP 76-331. The percentage of seedlings with sucrose content  $\geq$  12% was higher in F<sub>2</sub> and BC<sub>1</sub> generations than in the F<sub>1</sub>.



Table 4. Frequency distribution (%) for stalk diameter (mm) in the F<sub>1</sub>, F<sub>2</sub> and BC<sub>1</sub> generations in crosses between *Saccharum* and its related genera.

Cross	Generation	Class center in millimeters, mm											% Progeny ≥ 19 mm in		C.V. (%)
		7	9	11	13	15	17	19	21	23	25	27	Stalk diam.	Mean	
CP 65-357	Parent *													29.00	
IS 76-178	Parent *													20.00	
CP 65-357 x IS 76-178	F <sub>1</sub> *				17	17	33	17	16				33	17.00	19.95
US 87-1016(F <sub>1</sub> ) selfed	F <sub>2</sub>	1	1	4	8	13	19	23	18	10	3		41	18.02	20.23
NCo 310	Parent *													27.00	
US 56-42-3	Parent *													10.04	
NCo 310 x US 56-42-3	F <sub>1</sub> *			3	22	43	30	2					2	15.45	13.19
US 87-1022(F <sub>1</sub> ) x CP 76-331	BC <sub>1</sub>		1	3	6	29	27	17	11	2	2	2	23	17.18	18.73
US 87-1022(F <sub>1</sub> ) x 'Sylva'	BC <sub>1</sub>		12	26	31	16	11						2	13.00	20.16
US 87-1022(F <sub>1</sub> ) x CP 68-350	BC <sub>1</sub>			17	44	28	11						5	15.66	11.34

\*The F<sub>1</sub> seedlings and their parental clones were grown in 1986/87.

There were no significant increases in stalk diameter in the F<sub>2</sub> and BC<sub>1</sub> generations from the F<sub>1</sub> generation in a cross between CP 65-357 and *Miscanthidium sorghum* (US 87-1022) as shown in Table 3. Therefore, F<sub>2</sub> and BC<sub>1</sub> seedlings produced by the same F<sub>1</sub> hybrids from crosses between *Saccharum* and its related genera were planted in 1989/90 to re-examine segregation patterns for stalk diameter in the F<sub>2</sub> and BC<sub>1</sub> generations. The results from the 1989/90 experiment also indicated that US 87-1016 (F<sub>1</sub>) from a cross between CP 65-357 and IS 76-178 produced a relatively higher mean stalk diameter in the F<sub>2</sub> and BC<sub>1</sub> seedling populations than did those in the F<sub>2</sub> and BC<sub>1</sub> from crosses between NCo310 and *Miscanthus* and between NCo 310 and *Miscanthidium* (Table 6). Both experiments (Tables 4 and 6) indicated that although the F<sub>2</sub> and BC<sub>1</sub> generation means did not markedly change from that of the F<sub>1</sub> generation, the percentages of F<sub>2</sub> and BC<sub>1</sub> seedlings with stalk diameter ≥ 19mm increased considerably. The BC<sub>1</sub> seedlings had up to 4mm larger stalk diameter than F<sub>2</sub> seedlings. The modes of the frequency distribution of BC<sub>1</sub> seedlings also moved approximately 2mm more toward larger stalk diameter than those of the F<sub>2</sub> seedlings. The changes in population characteristics suggested that the F<sub>1</sub> tassels, which were used in backcrosses, might not have been completely male-sterile when collected from the field, and pollen of female parents possibly affected the frequency distribution of the BC<sub>1</sub> seedling populations.

Most F<sub>1</sub> hybrids used in this study appeared to be strong males. Neither backcrossing nor self-fertilization appeared to be very effective in increasing the frequency seedlings with acceptable stalk diameter in F<sub>2</sub> and BC<sub>1</sub> progenies (Table 6). Therefore, an attempt was made to modify the pollination pattern by sterilizing F<sub>1</sub> tassels by the hot-water emasculation and then pollinating with commercial sugarcane cultivar pollen. These results indicated that the modes of the frequency distribution of the BC<sub>1</sub> populations were moved toward the larger stalk diameter of commercial types by 4mm and away from those of the F<sub>2</sub> seedling populations by 4mm (mode: 18mm vs 10mm, respectively) (Table 7). However, the difference of the average C.V.(%) between F<sub>2</sub> and BC<sub>1</sub> was very small (17.77% vs 16.07%, respectively). The average percentage of seedlings with stalk diameter ≥ 19mm was much greater in the BC<sub>1</sub> generation than in the F<sub>2</sub> (48% vs 3%, respectively). When hot water emasculated F<sub>1</sub> tassels were pollinated with commercial sugarcane cultivar pollen marked changes in the characteristics of the frequency distribution of the stalk diameter of the BC<sub>1</sub> seedling populations were observed. More studies are needed to determine whether other characters would respond to the treatment in a similar fashion by insuring that true backcrosses are obtained. Also, more investigations are needed to determine whether the use of complete male-sterile F<sub>1</sub> hybrids crossed with sugarcane cultivar pollen and the use of complete male-sterile sugarcane cultivars crossed with the F<sub>1</sub> pollen would produce same results as they did in this study.

Table 5. Frequency distribution (%) for percent sucrose in the  $F_1$ ,  $F_2$  and  $BC_1$  generations in crosses between *Saccharum* and its related genera.

Cross	Generation	Class center in percents									% Seedlings ≥ 12% in Sucrose	Mean	C.V. (%)
		2	4	6	8	10	12	14	16				
CP 65-357	Parent*										15.85		
IS 76-178	Parent*										1.33		
CP 65-357 x IS 76-178	F <sub>1</sub> *	17	66	17						0	5.85	23.86	
US 87-1016 (F <sub>1</sub> ) selfed	F <sub>2</sub>				3	10	40	20	27	40	12.11	19.41	
NCo 310	Parent*										10.84		
US 56-42-3	Parent*										0.98		
NCo 310 x US 56-42-3	F <sub>1</sub> *	24	41	30	5					0	4.32	3.44	
US 87-1022 (F <sub>1</sub> ) x CP 76-331	BC <sub>1</sub>				17	33	33	13		33	12.01	18.17	
US 87-1022 (F <sub>1</sub> ) x 'Sylvia'	BC <sup>1</sup>			17	23	30	27	3		10	10.14	22.89	
US 87-1022 (F <sub>1</sub> ) x CP 68-350	BC <sub>1</sub>			12	18	29	29	6	6	4	10.32	40.42	

\* The  $F_1$  seedlings and their parental clones were grown in 1986/87.

Table 6. Frequency distributions (%) for stalk diameter (mm) in the  $F_1$ ,  $F_2$  and  $BC_1$  generations in crosses between *Saccharum* and its related genera.

Cross	Generation	Class center in millimeters, mm											% Progeny ≥ 19 mm in Stalk diam. Mean		C.V. (%)
		9	11	13	15	17	19	21	23	25	27	29			
<u>Interspecific hybrid sugarcane cultivar x Erianthus</u>															
CP 65-357 x IS 76-178	F <sub>1</sub> +			17	17	33	17	16					33	17.00	19.95
US 87-1016(F <sub>1</sub> ) selfed	F <sub>2</sub>	4		15	15	19	31	12	4				38	17.12def*	18.70
US 87-1016(F <sub>1</sub> ) x CP 80-1827	BC <sub>1</sub>			4	14	18	33	21	9				48	18.68gh	14.17
US 87-1016(F <sub>1</sub> ) x CP 82-2043	BC <sub>1</sub>	2		8	10	25	28	19	6	2			43	18.20fgh	16.17

Interspecific hybrid sugarcane cultivar x Erianthus

Table 6. Con't. Frequency distributions (%) for stalk diameter (mm) in the F<sub>1</sub>, F<sub>2</sub> and BC<sub>1</sub> generations in crosses between *Saccharum* and its related genera.

Cross	Generation	Class center in millimeters, mm											% Progeny ≥ 19 mm in		C.V. (%)
		9	11	13	15	17	19	21	23	25	27	29	Stalk diam.	Mean	
<u>Interspecific hybrid sugarcane cultivar x Miscanthus</u>															
NCo 310 x PI 3905	F <sub>1</sub> +		5	25	35	30	5						05	15.52	13.19
US 87-1019(F <sub>1</sub> ) selfed	F <sub>2</sub>	1	2	12	34	37	10	4					07	16.00bcde	13.59
NCo 310 x US 47-11	F <sub>1</sub> +		18	40	32	10							0	13.96	12.51
US 87-1020(F <sub>1</sub> ) selfed	F <sub>2</sub>	1	10	19	32	24	11	1	2				11	15.30bc	17.37
US 87-1020(F <sub>1</sub> ) x CP 82-2043	BC <sub>1</sub>		24	29	42	3	2						2	13.60a	13.78
US 87-1021(F <sub>1</sub> ) selfed	F <sub>2</sub>		8	8	36	28	8	8	4				12	16.20cde	17.55
US 87-1021(F <sub>1</sub> ) x CP 83-1773	BC <sub>1</sub>		2	4	27	32	23	9	3				28	17.18ef	14.15
US 87-1021(F <sub>1</sub> ) x CP 82-2043	BC <sub>1</sub>		1	8	20	39	19	11	2				23	17.16ef	13.95
<u>Interspecific hybrid sugarcane cultivar x Miscanthus</u>															
NCo 310 x US 56-22-3	F <sub>1</sub> +		10	32	29	19	10						10	14.83	13.33
US 87-1024(F <sub>1</sub> ) selfed	F <sub>2</sub>	2	5	22	28	29	11	3					19	15.44bc	16.22
US 87-1025(F <sub>1</sub> ) selfed	F <sub>2</sub>	1	5	24	26	27	9	6	2				16	15.68bcd	17.71
US 87-1025(F <sub>1</sub> ) x CP 82-1505	BC <sub>1</sub>	3	2	2	10	17	28	25	10	2	1		53	18.78h	17.90
<u>Interspecific hybrid sugarcane cultivar x Miscanthidium</u>															
NCo 310 x US 56-42-3	F <sub>1</sub> +		3	22	43	30	2						2	15.45	13.19
US 87-1022 (F <sub>1</sub> ) selfed	F <sub>2</sub>		14	29	29	20	7	1					4	14.60ab	16.17
US 87-1022 (F <sub>1</sub> ) x CP 81-1425	BC <sub>1</sub>	1	2	13	17	22	21	18	4	2			37	17.48efg	18.48

\* Means followed by the same letter were not significantly different at the 0.05 level.

+ The F<sub>1</sub> seedlings were grown in 1986/87 and excluded from the statistical analysis in the F<sub>2</sub> and BC<sub>1</sub> test.

Table 7. Frequency distributions (%) for stalk diameter (mm) in the F<sub>2</sub> and BC<sub>1</sub> generations in crosses between *Saccharum* and its related genera when F<sub>1</sub> tassels treated with hot water.

Cross	Generation	Class center in millimeters, mm												% Progeny ≥ 19 mm in Stalk diam. Mean		C.V. (%)
		7	9	11	13	15	17	19	21	23	25	27	29			
<u>NCo 310 x PI 3905</u>																
US 87-1018(F <sub>1</sub> ) selfed	F <sub>2</sub>			6	25	28	26	11	2	1				1	13.29a	*21.02
+US 87-1018(F <sub>1</sub> ) x CP 83-1281	BC <sub>1</sub>					1	2	8	21	20	36	9	3	28	17.32c	15.72
<u>NCo 310 x PI 3905</u>																
US 87-1019(F <sub>1</sub> ) selfed	F <sub>2</sub>			1	2	12	34	37	10	4				7	16.00b	13.59
+US 87-1019(F <sub>1</sub> ) x CP 83-1939	BC <sub>1</sub>				4	16	8	13	20	24	13	2		50	18.26d	20.09
US 87-1019(F <sub>1</sub> ) x CP 85-830	BC <sub>1</sub>			1	4	15	37	19	13	7	2	2		19	16.16b	18.55
<u>NCo 310x US 56-42-3</u>																
US 87-1023(F <sub>1</sub> ) selfed	F <sub>2</sub>		310	26	31	14	13	3						1	12.88a	18.71
+US 87-1023(F <sub>1</sub> ) x CP 83-1281	BC <sub>1</sub>					15	17	31	25	19	2			65	19.92e	12.39

\* Means within a column followed by same letter were not significantly different at the 0.05 level.

+ F<sub>1</sub> tassels treated with hot water at 49°C for 10 minutes.

Both Stebbins (13) and Allard (1) list four generalizations about interspecific hybridization and its effects. These generalizations include: 1). The tremendous diversity in the F<sub>2</sub> and later generations is a result of the extreme heterozygosity of interspecific F<sub>1</sub> hybrids. 2). Although segregation in the F<sub>2</sub> of an interspecific hybrid produces a very large number of recombination types, these are by no means a random sample of the total array of possible combinations of the phenotypic characteristics of the parents. 3). Segregation often does not fit classical Mendelian patterns due to the abnormality of the meiotic process in interspecific hybrids. 4). Self-fertilization has much the same effect as backcrossing to one of the parents and segregants nearer to one or the other parental species in characters of adaptive value have better chances of survival. These general characteristics about interspecific hybridization may be applied to the intergeneric hybrids. Interspecific hybrid sugarcane cultivars have been selected for larger stalk diameter, high sugar content, high yield, etc. These characteristics are probably against the sugarcane cultivars' adaptive value under natural environment. Crosses between the interspecific hybrid sugarcane cultivars and their related genera produce F<sub>1</sub> hybrids which appear to have a higher adaptive value than their sugarcane cultivar parents. These results also strongly indicate that plant types closer to the sugarcane cultivar parent were far less common than intermediates among F<sub>2</sub> seedlings examined.

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# USE OF AN ENZYME-LINKED IMMUNOSORBENT ASSAY TO DETECT THE LEAF SCALD PATHOGEN, *XANTHOMONAS ALBILINEANS*, IN SUGARCANE

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## ABSTRACT

A commercially-available monoclonal antibody, specific to the genus *Xanthomonas*, was used to detect *Xanthomonas albilineans* in naturally-infected sugarcane stalks. In indirect ELISA, the monoclonal antibody reacted with pure cultures of *X. albilineans* and extracts from symptomatic stalks but not with extracts from healthy stalks or pure cultures of two other bacterial pathogens of sugarcane. The ELISA and isolation techniques detected *X. albilineans* in 75.8 and 69.7 %, respectively, of the extracts from leaf scald symptomatic stalks. In extracts prepared from asymptomatic stalks, *X. albilineans* was detected in 9.7 and 32.3 % of the stalks with ELISA and isolation procedures, respectively. Preliminary tests with ELISA amplification procedures show promise for increasing the sensitivity of the ELISA assay.

## INTRODUCTION

Leaf scald, caused by the bacterium *Xanthomonas albilineans* (Ashby) Dowson, is a disease which limits the cultivation of susceptible cultivars of sugarcane in most areas of the world where the disease is present (6). Leaf scald was reported in Florida in 1967 (2), but the disease is largely confined to unreleased cultivars in the United States Department of Agriculture - Agricultural Research Service (USDA-ARS) breeding and selection program at Canal Point. As part of the USDA-ARS program, cultivars in later stages of the selection program are tested at outfield locations on commercial farms. With the presence of leaf scald at Canal Point, there has been concern that it could be spread in seed-cane to industry locations. The risk is enhanced by the facts that leaf scald can exist as latent infections over long periods of time (6) and that the pathogen can exist in low populations in the host.

Several serological procedures utilizing micro-agglutination (5), immunofluorescent staining (3,8), and enzyme-linked immunosorbent assays (4,6) have been used with varying degrees of success to diagnose leaf scald. However, the polyclonal serum used in each instance was produced against a single strain or isolate of *X. albilineans* (Xa). Worldwide, at least three serotypes of Xa are known to exist (7), thus, the available polyclonal sera may not be used with equal effectiveness against all serotypes. This is a serious limitation for quarantine and screening programs. Presently, no data is published describing the multiplicity of serotypes, if any, within Florida isolates. Recently, a monoclonal antibody was produced that is specific for species of bacteria in the genus *Xanthomonas* (1). Of the two diseases of sugarcane caused by *Xanthomonas* species, leaf scald and gumming disease, only leaf scald is present in Florida. Therefore, the use of this monoclonal has potential applications in serological detection techniques for leaf scald in Florida sugarcane. This report presents the results of the initial testing to detect leaf scald using this monoclonal antibody in an enzyme-linked immunosorbent assay (ELISA).

## MATERIALS AND METHODS

**Source of infected material.** Stalks were cut from plants in the early stages of the USDA-ARS selection program at Canal Point. Three types of stalks were evaluated. "Symptomatic" stalks were those that showed pencil-line streaks, wilting or necrosis of top leaves, and/or abundant lateral shoots. "Asymptomatic" stalks were stalks displaying no symptoms growing from stools with one or more "symptomatic" stalks. Stalks labeled as "healthy" were cut from plots or cultivars with no visible symptoms of leaf scald. In the initial testing, healthy stalks were also obtained from plots in the breeding program of the United States Sugar Corporation, an area where leaf scald has not been observed.

Samples consisted of a single internode taken from the stalk three-quarters up the hardened stalk. Two cores, approximately 2-3 cm long by 1.6 cm in diameter, were excised from each internode sample using a clean cork borer. Each core was placed in a 50 ml centrifuge tube and centrifuged at 3000 - 7500 X g for 7 - 10 min. The sap from each of the two tubes was vortexed and then combined to form one sample which was used for both the isolation and ELISA assays. Generally, 0.75 to 1.5 ml of sap was obtained.

**Isolation procedures.** Sap extracted from the stalks by centrifugation was either streaked or dilution plated on to Wilbrinks agar (peptone, 5g; yeast extract, 5g; sucrose, 10g;  $K_2HPO_4$ , 0.5g;  $MgSO_4$ , 0.25g; agar, 15g;  $H_2O$ , 1000 ml) immediately after extraction. Isolation plates were incubated at 30 C and examined at 48 hrs and 96 - 120 hrs to determine the recovery of bacterial contaminants and Xa, respectively, from the sap samples. Identification of Xa was based primarily on colony morphology and its' slow growth rate. Questionable Xa colonies were frequently tested by ELISA. After the isolation procedures were performed, the sap samples were then either processed immediately for ELISA or stored at -20 C for subsequent processing.

**ELISA assays.** Two types of indirect ELISA were used. In both assays, a commercially available *Xanthomonas*-specific monoclonal antibody (Agdia, Inc., Elkhart, Indiana) was used. For both assays, sap obtained by centrifugation was transferred to a 1.5 ml microcentrifuge tube and centrifuged at 8500 X g for 10 min. The supernatant was discarded and the pellet was resuspended in 200  $\mu$ l of 0.05M carbonate-bicarbonate buffer (pH 9.6). The bacteria were adsorbed to the wells of polystyrene microtiter plates (Dynatech Laboratories, Inc., Alexandria, VA) by placing 100  $\mu$ l of the suspension into each of two wells and drying the plates overnight at 35 C. To the dried plate, 200  $\mu$ l/well of phosphate buffered saline + 0.05% Tween 20 (PBST) + 5% skim milk were added and incubated for 30 min at room temperature. After incubation (and between all subsequent steps of the procedure), the plate was rinsed three times with PBST. The *Xanthomonas* specific monoclonal antibody (XMCA) as supplied by Agdia, was diluted 1:100 in PBST + 2.5% skim milk and 100  $\mu$ l/well were added and incubated 1 hr at 30 C. After incubation with the primary antibody, 100  $\mu$ l/well of a 1:1000 dilution of a goat antimouse-alkaline phosphatase antibody conjugate (Sigma Chemical Co., St. Louis, MO) in PBST + 2.5% skim milk was added and incubated for 1 hr at 30 C. The plate was washed and then one of two types of substrates was added.

For the majority of the assays (unamplified ELISA), 100  $\mu$ l/well of a 0.6 mg/ml solution of p-nitrophenyl phosphate disodium salt (PNPP) in 10% diethanolamine (pH 9.8) was added and incubated for 45 - 60 min at room temperature. The absorbance at 405nm ( $A_{405}$ ) was measured on a Biotek EIA reader, model EL 309 (Biotek Instruments, Burlington, VT). For the amplified ELISA, a substrate prepared by the method of Stanley et al (9) was used. To each well, 100  $\mu$ l of 0.2mM nicotinamide-adenine dinucleotide phosphate monosodium salt, in 0.05M diethanolamine buffer (pH 9.6) was added and incubated for 30 min at room temperature. After incubation, remaining alkaline phosphatase activity was blocked by adding 15  $\mu$ l/well of 0.05M PNPP in 0.025M phosphate buffer (pH 7.0). Subsequently, 150  $\mu$ l/well of the amplification mixture was added. The amplification mixture consisted of 700 units of alcohol dehydrogenase, 100 units of lipoamide dehydrogenase (type VI), 3% (v/v) ethanol, and 1mM p-iodonitrotetrazolium violet in 14.5 ml of 0.025M phosphate buffer. Color development was allowed to proceed at room temperature for 15 - 30 min before absorbance values at 490 nm ( $A_{490}$ ) were determined on the plate reader.

For both types of ELISA assays, the plates were blanked on wells that did not receive bacterial suspensions. The threshold for positive samples was the greater of 3X the absorbance value from a healthy sample or absorbance ( $A_{405}$  or  $A_{490}$ ) values greater than 0.05 OD units.

## RESULTS AND DISCUSSION

Initially samples were assayed by direct streaking on Wilbrinks agar and by the unamplified ELISA. A total of 66, 62, and 21 samples were assayed using these methods for symptomatic, asymptomatic, and healthy stalks, respectively. Of the symptomatic stalks, Xa was detected by both the ELISA and isolation methods in 40 (60.6%) samples (Table 1). In 10 samples (15.2%) Xa was detected by ELISA and not by isolation; in 6 samples (9.1%) Xa was detected by isolation and not by ELISA. In the 10 samples in which Xa was detected only by ELISA, the isolation plates contained high numbers of virtually pure cultures of non-Xa bacteria. Although isolated from plant sap, they will be referred to as contaminants. Subcultures of these contaminants gave negative test results by ELISA indicating that the Xa present in the original samples was overgrown and suppressed by the contaminating bacteria. On isolation plates where both contaminants and Xa were present, zones of inhibition were often observed around the contaminant colonies. Where Xa was detected in stalk samples only by isolation, both the population levels of Xa and



contaminants were low. Xa was not detected in 10 stalks (15.2%) by either method. However, a large number of the samples were collected after a severe freeze on December 24 - 25, 1989 which resulted in wide spread apical meristem damage. Freeze damaged stalks have many of the same symptoms as scald-infected stalks, i.e. death of whorl leaves, internal discoloration, side shooting, etc. Non-infected, freeze-damaged stalks may have been included among the symptomatic samples.

Table 1. Comparison of diagnostic techniques for symptomatic stalks.

Number of samples = 66			
Possible test outcome			
ELISA	Isolation	Number of samples	% of total
+	+	40	60.6
+	-*	10	15.2
-	+	6	9.1
-	-	10	15.2

\*Bacterial contaminants present in high numbers.

Xa was detected by both the isolation and ELISA methods in six samples (9.7%) from asymptomatic stalks. Unlike samples from symptomatic stalks, no samples from asymptomatic stalks showed positive results for the presence of Xa by ELISA only (Table 2). In 14 samples (22.6%), Xa was detected only by the isolation method, and in most of these instances, the Xa population levels were low. Bacterial contaminants were not found in large numbers in the asymptomatic stalks. Xa was not detected by either method in 42 samples (67.7%) of asymptomatic stalks or in 21 samples from healthy stalks (Table 3).

Table 2. Comparison of diagnostic techniques for asymptomatic stalks.

Number of samples = 62			
Possible test outcome			
ELISA	Isolation	Number of samples	% of total
+	+	6	9.7
+	-	0	0.0
-	+	14	22.6
-	-	42	67.7

Table 3. Comparison of diagnostic techniques for healthy stalks.

Number of samples = 21			
Possible test outcome			
ELISA	Isolation	Number of samples	% of total
+	+	0	0.0
+	-	0	0.0
-	+	0	0.0
-	-	21	100.0

Using pure cultures of Xa, concentrations of approximately  $2 \times 10^5$  cells/well could be detected in the unamplified ELISA. Preliminary tests with the amplified ELISA gave a 25 fold increase in sensitivity over the



unamplified ELISA using bacterial cultures. A comparison of both ELISA methods and the dilution plating isolation method was performed on samples from a mixture of 35 symptomatic and asymptomatic stalks (Table 4). Utilizing the unamplified ELISA, Xa was detected in seven samples with a mean  $A_{405}$  of 0.352. Using the amplified ELISA, Xa was detected in a total of 11 samples with a mean  $A_{490}$  of 1.555. Xa was detected by isolation in a total of 11 samples. The mean Xa population level in stalks where Xa was detected by both the isolation procedure and by one of the ELISA procedures was in the range of  $3-4 \times 10^8$  cells/ml of sap. In the samples in which Xa was detected by isolation and not by ELISA, the mean Xa populations were  $2 \times 10^6$  and  $3 \times 10^5$  cells/ml for the unamplified and amplified ELISA assays, respectively. The combination of higher absorbance readings and lower detection thresholds in the amplified ELISA indicates that the amplified ELISA is approximately 10-fold more sensitive under actual use conditions than the unamplified ELISA. As far as total number of samples in which Xa was detected, the amplified ELISA detected an equal number of positive samples as the isolation method. Although both methods were more sensitive than the unamplified ELISA, each method missed Xa in some instances that the other method detected.

Table 4. Comparison of isolation, ELISA, and amplified-ELISA techniques for detecting *Xanthomonas albilineans* in a mixture of 35 symptomatic and asymptomatic stalks.

ELISA	Isolation	Standard ELISA			Amplified ELISA		
		Number of samples	Mean $A_{405}$	Mean Xa conc.	Numbers of samples	Mean $A_{490}$	Mean Xa conc.
+	+	5	0.364	$4 \times 10^8$	8	1.452	$3 \times 10^8$
+	-	2	0.322	$<4 \times 10^3$	3	1.828	$<4 \times 10^3$
-	+	6	-0.011	$2 \times 10^6$	3	0.001	$3 \times 10^5$
-	-	22	-0.013	$<4 \times 10^3$	21	-0.008	$<4 \times 10^3$

<sup>1</sup>The threshold for detection in the plating assays was  $4 \times 10^3$  cells/ml.

In addition to sap from symptomatic, asymptomatic, and healthy stalks, the ELISA assay was tested against a variety of other samples representative of situations and other bacteria that may be encountered. Using the unamplified ELISA, the XMCA did not react with difusates from healthy leaves macerated in PBST, a pure culture of *Clavibacter xyli* subsp. *xyli* (casual agent of ratoon stunting disease), sap extracted from scald-free stalks infected with ratoon stunting disease, a pure culture of *Pseudomonas rubrisubalbicans* (causal agent of mottled stripe of sugarcane), or pure cultures of any of the common bacterial contaminants encountered during the isolation procedures. Positive XMCA reactions were obtained, however, with diffusates from leaves showing pencil-line streaks typical of leaf scald infection.

We conclude that the XMCA detects Xa and does not react with healthy stalk extracts or other commonly encountered bacterial flora in sugarcane. Since only one bacterial pathogen of sugarcane in the genus *Xanthomonas* is present in Florida, a positive reaction in an ELISA assay utilizing XMCA is presumptive evidence of leaf scald infection. The unamplified ELISA assay is useful for confirming the diagnosis of leaf scald directly in sap extracted from symptomatic stalks and for verifying the identity of suspect colonies on isolation plates. Since the ELISA method is not affected by the presence of bacterial contaminants, the ELISA procedure can be more sensitive than isolation for specimens showing leaf scald-like symptoms. However, the unamplified ELISA is apparently not sensitive enough in its present form to detect all latent infection. The amplified ELISA procedure is more sensitive than the unamplified ELISA and may have potential for the detection of Xa in stalks with latent infection. When the isolation procedure and amplified ELISA were evaluated together, each procedure missed Xa in samples that the other procedure was able to detect. Thus, in situations where latent infections are suspected, more than one procedure should be used to attempt to detect Xa.

Although some preliminary work was conducted to determine the best sampling protocol for the work presented here, little information is available on the population dynamics of Xa within stalks and during the course of the disease. Research to develop optimum sampling procedures may improve the detection methods.

The use of XMCA has other potential benefits. Since the XMCA is specific for the genus, this single antibody should be capable of detecting all three serovars of Xa as well as *Xanthomonas campestris* p.v. *vasculorum* (Cobb) Dye, the causal agent of gumming disease. Thus, the use of XMCA has potential applications in a quarantine program where the exclusion of both diseases is necessary. Also by making the appropriate conjugates, the XMCA could be altered for use in other types of assays such as the immunofluorescent staining technique used elsewhere (8) without the drawbacks of a polyclonal serum.

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## EXPRESSION OF SUGARCANE STALK CHARACTERISTICS AS INFLUENCED BY EXTREME WATER REGIMES

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### ABSTRACT

Pith in sugarcane is considered an undesirable characteristic which is thought to reduce sugar yield. The purpose of this study was to investigate the influence of environment (soil water) on the expression of pith, pipe and cracking, all of which are characters that are evaluated in early stages of selection. Twelve sugarcane clones, which had a range of expression for these characters, were subjected to three water treatments: dry, control (normal), and flood. The ratio of pith/pipe to stalk diameter was numerically but not statistically greatest in the flood treatment, which also yielded the lowest juice extraction by weight and by volume. However, there was no significant correlation between extraction by weight and pith and pipe, thus other stalk characters such as fiber and rind thickness may influence extraction. Density was correlated with the amount of pith and pipe, but not with extraction by weight or volume. Cracking was not significantly affected by treatment. Selection against pith or pipe should be made only when expression is extreme.

### INTRODUCTION

Selection of sugarcane (*Saccharum* spp.) clones in the early stages of the Florida sugarcane breeding program at Canal Point is based solely on obvious physical attributes such as stalk size (diameter and height), disease reaction, stalk number, and lodging. No mill samples are taken, so selection is essentially for biomass. Certain characteristics that are selected against, such as stalk cracks, pithiness, and pipe (tube), are perceived as detrimental, but the effect of environment on their expression has not been determined (Verma, 1948; Van Dillewijn, 1952; Evans, 1966). In addition, the relationship of pithiness and pipe to yield is not satisfactorily understood.

Two kinds of stalk cracking are identified in sugarcane (Van Dillewijn, 1952). Corky cracks are a shallow scoring of the cuticle, and are of minor importance. The subject of this study was rind cracks, deep lesions which may extend completely through the rind. Such cracks may permit the entry of pathogens, resulting in spoilage of stalks; rind cracks can also weaken stalk structure causing lodging. Van Dillewijn (1952) reported that cracking was associated with varieties but was also influenced by growing conditions.

Pith and pipe both occur in the core of the stalk. Pith is a juiceless, spongy parenchyma, whereas pipe is an actual cavity. Pith related to flowering (Evans, 1966; Van Dillewijn, 1952) is found mostly in the upper region of the stalk. Breeding programs are concerned with pith that is found in immature, non-flowering cane and frequently extends the length of the stalk. Pith and pipe have been attributed variously to cultivar, drought stress, lush growth (Evans, 1966) and soil type (Van Dillewijn, 1952; Anonymous, 1933). However, further work is necessary in quantifying pith and pipe and the role of environment in their expression.

In addition to the causes of pith and pipe, the relationship of these characters to yield is not satisfactorily understood. Selection is based on the assumption that pith and pipe reduce storage tissue (Lakshmikantham, 1946) and consequently, juice extraction (juice weight/total stalk weight). Pith and pipe would be expected to reduce density, also which is a component of yield (Miller and James, 1971; Gravois, et al. 1990).



Since water is a major feature of the Everglades environment and varies in abundance in our research fields, it was chosen as an environmental treatment. This experiment was not concerned with precise monitoring or management of water. Rather, water was a convenient and easily managed variable with which different environments could be created. This experiment sought to: 1) quantify the effect of environment (water) on the characters under study, 2) investigate the relationship of pith and pipe to yield.

## MATERIALS AND METHODS

Twelve sugarcane clones were selected for their various expression of cracks, pith and pipe, and diameter (Table 1). Expression ranged from a completely solid clone with no pith or pipe (X84-633B) to an extremely pithy entry, X84-633D and one with pronounced piping (MISC.). Single-eye pieces were germinated in flats in the greenhouse in the winter of 1988 and then transplanted into 38-liter plastic cans containing 50% field soil and 50% masonry sand on 21, March 1988. Each can contained one stool.

Table 1. Clones selected for various expression of internal and external stalk characters.

<u>Clone</u>	<u>Character</u>
CP 57-603	large diameter
CP 72-1210	slight pipe and cracking
CP 84-1840	very cracky
CP 85-1773	narrow diameter
MISC.	large pipe, large diameter
X 84-579	moderate pith, few cracks
X 84-589	pithy
X 84-633B	solid, very narrow diameter
X 84-633C	solid
X 84-633D	very pithy
X 84-633E	moderately cracky
X 84-84	pithy

Because of limited greenhouse space, cans were arranged outdoors in three water treatments: flood, control, and dry. Clones were randomized and replicated eight times per treatment (96 cans per treatment). In the flooded treatment, each can was placed in a 20 cm deep rubber feed tub. Cans were filled with water once daily to the point where the can and feed tub overflowed. Thus, with no drainage, the soil was flooded until evapotranspiration reduced the water level. Since the feed tubs were always full, the soil was frequently flooded or at least saturated to within 15-20 cm of the soil surface. The control treatment was a daily watering with a drip system that is used to maintain clones for crossing, where excess water could be drained from the cans. The dry treatment was watered by rainfall and supplemented when stress symptoms were obvious. Water treatments commenced on 3 June 1988 when plants were well-established and tillered.

From 16-20 September 1988, measurements were taken on cracks, diameter, pith, pipe, stalk weight, stalk volume and number of internodes. Diameter was measured at the center of the internode perpendicular to the eye at about 1.5 m above ground. Four stalks were measured per stool. The number of cracks and internodes was counted for each stalk of a three-stalk sample. To evaluate all clones on the same basis, a ratio of number of cracks to number of internodes was calculated. Diameter of pipe or pith was measured at the top one quarter, middle, and bottom one quarter of each stalk of a two-stalk sample. Each diameter was recorded as either pith or pipe. However, for some data analysis the distinction between pith and pipe was not made. The diameter of the non-productive area (pith or pipe) was divided by the stalk diameter to provide a ratio by which all clones could be compared. Another two-stalk sample was weighed, measured for volume, and milled to extract juice, which was also weighed. Volume of cane was measured by weight of water displaced when a sample was totally submerged in a tank. Stalk density was calculated as stalk weight divided by volume and extraction by weight (EXT-W) was calculated as juice weight divided by stalk weight. A second extraction (EXT-V) was calculated by dividing the juice weight by the stalk volume.

Since water treatments could not be randomized, clones were nested within treatments. Analyses of variance were calculated for characters under study and means were separated with an LSD test (Carmer and Walker, 1985). Correlation coefficients of means for various treatment and character combinations were calculated and tested for significance.



## RESULTS AND DISCUSSIONS

The ratio of pith or pipe to diameter, and the rank of each treatment for each clone are presented in Table 2. Although the effect of irrigation treatments was not significant ( $P > 0.05$ ), (Table 3.) there was a trend for the flooded treatment to have the greatest amount of pith or pipe. Treatment means were not significantly different possibly due to insufficient replication. Ten of the twelve clones had their greatest pith or pipe ratio in that treatment. There was an increasing frequency of pipe in the lower quarter of the stalk for the flood treatment. This often occurred in clones which were solid in that region of the stalk in other treatments. Thus the greater ratio observed in the flooded treatment may be due to increased piping. This was substantiated by the pronounced increase in ratio in the flooded treatment of MISC., a clone which had a tendency for piping. On the other hand, very pithy clones, X84-633D and X84-589, did not increase in pith when flooded.

Table 2. Ratio of pith and/or pipe to diameter (cm) and the rank of treatments for each clone.

Clone	Dry		Treatment Control		Flood	
	Rank	Ratio	Rank	Ratio	Rank	Ratio
CP 57-603	2 <sup>1/</sup>	0.05	3	0.04	1	0.08
CP 72-1210	2	0.04	3	0.02	1	0.09
CP 84-1840	2	0.08	3	0.06	1	0.11
CP 85-1773	2	0.06	3	0.05	1	0.14
MISC.	2	0.17	3	0.16	1	0.26
X 84-579	1	0.21	3	0.08	2	0.11
X 84-589	1	0.33	2	0.31	3	0.27
X 84-633B	3	0.00	2	0.02	1	0.05
X 84-633C	3	0.05	2	0.06	1	0.15
X 84-633D	2	0.47	3	0.47	1	0.51
X 84-633E	3	0.02	2	0.02	1	0.10
X 84-84	3	0.06	2	0.07	1	0.09
Treatment Mean		0.13 n.s.		0.11 n.s.		0.16 n.s.

<sup>1/</sup> Ranks within a clone across treatments.

Juice extraction by weight (EXT-W) is the conventional method of calculating extraction. In the flood treatment, EXT-W was less ( $P < 0.05$ ) than the control and dry treatments (Tables 3, 4). Nine of the twelve clones had their lowest EXT-W in the flooded treatment. Reduced EXT-W may be due to the increased ratio of pith or pipe to diameter observed in the flood treatment. However, EXT-W appears to be affected by factors in addition to pith and pipe. The very solid clone X84-633B, had an EXT-W that was less than the extremely pithy clone, X84-633D, and MISC, which had a large pipe. This was probably due to the fact that X84-633B is a very thin cane. As such, it has a greater proportion of rind to juice-containing core. The clone MISC, on the other hand, is a large-barrelled cane with proportionately less rind. Thus although pith or pipe may affect EXT-W, other characteristics such as rind thickness and proportion, stalk diameter, and perhaps fiber must also be considered (Kang, et al, 1989).

Table 3. Analysis of variance for EXT-W, pith or pipe: diameter ratio, stalk density, and cracks per internode for twelve sugarcane clones.

Source	df	Pith: Diameter	Density	Cracks: Internodes Mean Squares	EXTW
Treatments (TMT)	2	0.06	0.02	0.59	0.05*
Clones in TMT	33	0.15**	0.02**	1.20**	0.01**
Reps in Clones	252	0.001	0.01	0.01	0.004

\*, \*\* Significance at alpha levels 0.05 and 0.01 respectively.

Table 4. Juice extraction by weight (EXT-W) and ranks of each treatment for each clone.

Clone	Dry		Treatment Control		Flood	
	Rank	Mean	Rank	Mean	Rank	Mean
CP 57-603	1	0.60	2	0.59	3	0.55
CP 72-1210	1	0.56	2	0.53	3	0.48
CP 84-1840	1	0.52	2	0.51	3	0.47
CP 85-1773	1	0.52	2	0.50	3	0.47
MISC.	3	0.51	1	0.54	2	0.53
X 84-579	1	0.49	2	0.48	3	0.45
X 84-589	1	0.47	2.5	0.44	2.5	0.44
X 84-633B	1	0.49	2	0.47	3	0.43
X 84-633C	2.5	0.49	1	0.52	2.5	0.49
X 84-633D	1	0.53	2	0.49	3	0.45
X 84-633E	1	0.49	2	0.48	3	0.43
X 84-84	1	0.54	2	0.51	3	0.50
Treatment Mean		0.52A*		0.50A		0.47B

\* LSD  $\alpha$  0.05 = 0.029; treatment means followed by the same letter are not significantly different.

Correlations between EXT-W and diameter, and pith and pipe are listed in Table 5. There was no negative correlation ( $P > 0.10$ ) between pith and pipe and EXT-W in any treatment, further evidence that other factors play an important role in EXT-W. Stalk diameter, which affects the proportion of rind to core, was positively correlated to EXT-W in all treatments. It appears, then that when a cane has a greater portion of its weight made up of rind or other dense, juiceless tissue, it will have a reduced EXT-W. Pith or pipe may increase the proportion of weight attributable to rind by reducing the amount of productive parenchyma in the core. But diameter also affects the proportion of weight due to rind, regardless whether pith or pipe are present or not.

Table 5. Correlation coefficients of EXT-W and EXT-V with density, diameter, and pith and/or pipe ratio to diameter in each water treatment.

	<u>Treatment</u>							
	Dry	P =	Control	P =	Flood	P =	Overall	P =
<b>EXT-W:</b>								
Density	.477	n.s.*	.016	n.s.	.619	.05	.447	n.s.
Diameter	.564	.05	.834	.001	.771	.001	.787	.001
Pith & Pipe	-.196	n.s.	-.333	n.s.	-.112	n.s.	-.224	n.s.
<b>Density:</b>								
Pith & Pipe	-.660	.05	-.860	.001	-.555	.10	-.720	.01
<b>EXT-V:</b>								
Density	.347	n.s.	.559	.10	.036	n.s.	.222	n.s.
Diameter	.024	n.s.	.521	.10	.411	n.s.	.382	n.s.
Pith & Pipe	-.730	.01	-.759	.01	-.700	.01	-.784	.01

\* n.s. =  $P > .10$

Extraction by volume (EXT-V) also was less in the flood treatment than in the dry and control treatments (Table 6). Again, the flood treatment had the greatest amount of pith and pipe. Since pith and pipe occupy volume yet contribute no juice, it is logical that EXT-V should be affected. The negative correlation between EXT-

V and pith and pipe was significant ( $P < 0.01$ ) in all treatments (Table 5). However EXT-V was not as well correlated with diameter as was EXT-W.

Table 6. Juice extraction by volume (EXT-V) and ranks of each treatment for each clone.

Clone	Dry		Treatment Control		Flood	
	Rank	Mean	Rank	Mean	Rank	Mean
CP 57-603	2	0.606	1	0.651	3	0.568
CP 72-1210	2	0.583	1	0.608	3	0.535
CP 84-1840	2	0.554	1	0.561	3	0.506
CP 85-1773	1	0.609	2	0.544	3	0.535
MISC.	2	0.538	1	0.574	3	0.517
X 84-579	2	0.532	3	0.529	1	0.535
X 84-589	1	0.507	3	0.466	2	0.469
X 84-633B	1	0.582	2	0.554	3	0.495
X 84-633C	3	0.548	1	0.596	2	0.551
X 84-633D	1	0.520	2	0.497	3	0.454
X 84-633E	1	0.556	2	0.540	3	0.461
X 84-84	2	0.586	1	0.593	3	0.527
Overall		0.560A*		0.559A		0.513B

\* Treatment means followed by the same letter are not significantly different.  $LSD \alpha .01 = 0.045$ .

Stalk densities were not significantly different between treatments (Table 3). Increased proportion of pith or pipe was negatively correlated with density as expected (Table 5). Clones MISC. and X84-633D had the lowest densities overall. Conversely, X84-633B, the solid clone, had the greatest density overall. However, the clones with the lowest densities did not have the lowest EXT-W. There was a positive correlation between density and EXT-W, ( $P > 0.10$ ) in the flood treatment. Hence, even though density may be a minor component of yield, other factors such as diameter, and perhaps the content and type of fiber may mitigate the contribution of density to EXT-W and ultimately to yield.

Cracking of stalks was numerically greatest in the control treatment but treatments were not significantly different ( $P > .05$ ) (Table 3). Seven of eleven clones had their highest mean for cracking in the control. Clone 84-84 did not crack. The clone which had the greatest tendency to crack, 84-1840, had an equally high incidence of cracking in all treatments. The flood treatment had the least cracking in eight of twelve clones.

## CONCLUSIONS

Many sugarcane breeding facilities select against pith and pipe in their breeding nurseries. The results of this study, indicate environment, specifically available soil water, has limited effect on expression of characters frequently evaluated in early stages of selection. Numerical values for pipe in particular seemed to increase with excess water, but were not statistically significant.

The effect that pith and pipe have on sugar yield appears to be influenced by other factors and we suggest that diameter, rind thickness and perhaps type of fiber may be involved. All of these factors may influence the proportion of tissue which adds weight or occupies volume, yet does not produce much juice. From a practical stand point, it appears that selection against pith, and particularly pipe, should be made only when these characters are strongly expressed. If a clone has several favorable attributes, rejection because of moderate pith or pipe would not be justified. These conclusions are supported by Gravois, et al, (1990).

Further study of this problem should be conducted in various locations and environments where the effect of nutritional, climatic and hydrologic conditions could be evaluated.



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## DEVELOPMENT OF A PRACTICAL METHOD FOR SUGARCANE CROSS APPRAISAL

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### ABSTRACT

Current sugarcane (*Saccharum* spp.) cross appraisal methods are slow, unreliable and possibly impeded by cross by environment (CE) interaction. A fast, accurate and practical cross appraisal method is needed for sugarcane breeding programs. Identification of key traits and the degree of accuracy required in their measurement is critical to the development of an efficient appraisal method. The effect of CE on cross evaluation needs to be defined to refine these methods.

Ten crosses among 15 parents were evaluated at two locations in 1989. Data were collected on stool yield components from 50 progeny per cross. Mean component data were also determined for each cross from two 25-stalk samples, using one randomly selected stalk from each stool. Means, standard deviations and the probability of exceeding a target value (PROB) were calculated. The PROB assumed a normal distribution. Correlations between the PROB and the actual number of progeny exceeding the target value were very high ( $r=0.61$  to  $r=1.00$ ) thereby verifying the assumption of normality. The results indicated a strong CE interaction for stalks per stool, less interaction for the estimated stalk weight, and little interaction for stalk length, stalk diameter, Brix, pith or tube (hollow stalk). Correlations between locations were poor except for pith ( $0.89$ ), tube ( $r=0.90$ ), hand Brix ( $r=0.70$ ) and stalk diameter ( $r=0.58$ ). This suggested CE was important for many traits. Since the PROB was a precise estimate of the desirable proportion of genotypes in a cross's progeny, the PROB was considered the best estimate of cross performance. Correlations within locations among means, standard deviations, and the PROB suggested the mean value was an adequate predictor of cross worth.

Use of cross mean data would simplify data collection. A tenable cross appraisal method may be to evaluate about 50 progeny per cross in an evaluation block. The most promising crosses could be subsequently tested among locations. Mean stalk counts per stool would be determined before selection while stalk weight and sucrose content should be obtained soon after seedling selection before the regular harvest season to enhance selection for early maturity. Such data could then be used to plan future crosses, restrict selection to the most promising crosses and for parental evaluation.

### INTRODUCTION

The effectiveness and efficiency of a breeding program is limited by the quality of the initial unselected genotypes. An appraisal of the potential of a cross to produce elite progeny is needed to concentrate resources on the best crosses (20). Current sugarcane cross appraisal methods in Louisiana and elsewhere (7, 18, 22) commonly rely on the percent of the original progeny seedlings of a cross that are advanced to later stages of selection. This empirical method requires several years to estimate because selection rates in early stages are not reliable estimates of cross potential. The long delay between planting a cross and its evaluation wastes resources by the long retention and repeated plantings of inferior crosses in the selection program. An alternative method described by Arceneaux et al. (3) used replicated tests of cross progeny after they have undergone several years

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of screening. This method likely yields nonrepresentative results due to its use of selected progeny, is not practical in a full scale breeding program and provides no time advantage over the present method. A faster and more reliable method to appraise sugarcane families is needed.

Genotype by environment interaction (GE) in sugarcane clones is well known and has been reported by several investigators (1, 14, 21, 13, 15, 16). The degree of GE varies with the trait as well as region. Hogarth and Bull (11), and Pollock (17) have reported GE in the evaluation of sugarcane families. The Australian sugarcane growing region is much larger and more environmentally diverse than the Louisiana region. Australian breeding populations are also more nobilised than Louisiana populations. Results of Coleman et al. (6) suggested CE interaction existed in sugarcane populations bred for syrup production in Mississippi. A study by George (9) demonstrated cross by location interaction for several traits in sugarcane populations grown in Mauritius. The applicability of these studies to Louisiana sugarcane populations and environmental conditions is not known.

A study was conducted to develop a more effective cross appraisal method than the one currently used. The method must be practical on a full scale basis in a breeding program. An additional purpose of the study was to evaluate the need to replicate families across locations.

## MATERIALS AND METHODS

Ten crosses were made among 15 adapted parents at Houma, LA. Fifty randomly selected first-ratoon stools from each cross were evaluated at two locations: the Ardoyne Farm near Chacahoula, LA (Mhoon silt loam, fine-silty, mixed, nonacid, thermic Typic Fluvaquent) and the St. Gabriel Research Station, St. Gabriel, LA (Commerce silt loam, fine-silty, mixed, nonacid, thermic Aeric Fluvaquent). These locations are the normal sites of early selection for each of the breeding programs (Louisiana Agricultural Experiment Station or LAES, and United States Department of Agriculture or USDA). Families were not replicated at each location. Seedlings were established in the normal serpentine fashion that plants progeny from a cross in paired rows (41cm and 46cm intrarow spacing at St. Gabriel and Chacahoula, respectively; 183cm interrow spacing). Data were collected between September 25 and October 6, 1989 on an individual stool basis for stalk number per stool, stalk diameter, stalk length, Brix (percent soluble solids w/w) and a rating for pith and tube (rating 1 to 9, best = 1, worst = 9). Stalk diameter was estimated by the mean of three midstalk, internodal measurements without reference to the bud groove. Stalk length was estimated as the height from base to the last visible dewlap on one randomly chosen stalk per stool. Stalk weight was estimated using the length and diameter by assuming the stalk was a perfect cylinder with constant density. Estimated stool weight was calculated from the estimated stalk weight and stalk number. Brix was determined with a hand refractometer using the pooled juice obtained from midstalk punch samples of two stalks. Mean stalk weight and sucrose content were also determined from two 25-stalk samples, one stalk per stool, for each cross. From this pooled sample, cane sucrose content (theoretical recoverable sugar) was calculated with pol and Brix according to methods described by Legendre and Henderson (12) and Chen (5).

Means, standard deviations and the probability of exceeding a target value (PROB) were calculated. The PROB was similar to the method employed by George (10) and assumed a normal distribution. It was estimated by calculating a Z statistic and finding the associated probability of exceeding the target value where  $Z = (\text{mean} - \text{target}) / \text{SD}$  (19). Mean was the cross mean, target was an acceptable threshold (in this study it was the location mean plus one standard deviation) and SD was the cross standard deviation. For example, 30% of the progeny from a cross with  $11.4 \pm 6.0$  stalks per stool would on average exceed a target value of 14.7 stalks per stool (Table 2).

## RESULTS AND DISCUSSION

Analysis of variance established that cross by location interaction (considered CE) existed for all traits examined (Table 1). Crosses were considered different in most traits with the exception of stalk number, stalk length and estimated stalk weight. The significant CE for these traits renders evaluation of the main effects for cross and location potentially deceiving. It is the authors' opinion that meaningful differences existed among crosses for all traits.



Table 1. Analysis of variance of crosses among locations.

Source	df	Stalk number	Stalk length	Stalk diam.	Est. stalk wt.	Stool wt.	Hand Brix	Pith	Tube
		stool <sup>-2</sup>	cm <sup>2</sup>	cm <sup>2</sup>	kg <sup>2</sup>	kg <sup>2</sup>	% <sup>2</sup>		
Location	1	833.6**	5163 <sup>ns</sup>	1083.68**	3.935**	1.31 <sup>ns</sup>	1097.68**	1.089 <sup>ns</sup>	12.544 <sup>†</sup>
Cross	9	50.5 <sup>ns</sup>	18755 <sup>ns</sup>	59.46 <sup>†</sup>	0.793 <sup>ns</sup>	47.56 <sup>ns</sup>	64.60**	3.365**	21.420**
Cross x location	9	47.0 <sup>†</sup>	9427**	15.98 <sup>†</sup>	0.356**	64.61**	20.59**	0.342 <sup>ns</sup>	1.564 <sup>†</sup>
Error	980	27.2	742	9.37	0.673	19.15	2.91	0.577	0.889

†  $p \leq 0.10$ ; \*  $p \leq 0.05$ ; \*\*  $p \leq 0.01$ ; ns - not significant.

Since the genotypes were not replicated at the locations, interaction for the PROB and standard deviation of the crosses can only be appraised by direct examination of cross rank switching between locations. Results indicated a strong cross by location interaction for stalk number, less interaction for the estimated stalk weight and stool weight, and little interaction for stalk length, stalk diameter and Brix (Tables 2 and 3). Pith and tube ratings suggested cross by location interaction was unimportant (Table 3). Mean values of stalk weight, sucrose content and Brix supported the contention of interaction between some crosses and locations (Table 4). These observations appear in general concordance with clonal heritability estimates by Milligan et al. (16), although their results suggested more repeatable results would be expected for stalk weight than observed here. Differences among varietal response by location is likely due to climatic and local weather differences since the soil types were similar and the data were collected during the same time period. The Chacahoula location is commonly more mild in temperature range with slightly more precipitation than the St. Gabriel location. Generally, climatic differences between the locations are minor but sugarcane generally exhibits more robust growth at the Chacahoula location.

Correlations between locations were best for pith ( $r_{\text{PROB}} = 0.90$ ), tube ( $r_{\text{PROB}} = 0.89$ ) and hand Brix ( $r_{\text{PROB}} = 0.70$ ) (Table 5). Other characters were not significantly correlated between locations. Cross by environmental effects could have reduced the correlations of traits between locations. Assuming the low correlations were affected by the CE, then accurate cross appraisal methods would require an evaluation across locations to identify environmentally stable crosses.

Correlations among traits were calculated for each location on both a single stool basis and on a cross mean basis (25 stalk sample; Table 6). The correlations were generally very low for data derived from single stool observations. Major exceptions were the correlations among estimated stalk weight, stalk diameter, stalk length and stool weight. But this might be expected since the estimated stalk weight and stool weight were calculated using the stalk diameter and stalk length. Correlations of most traits with the mean stalk weight, estimated stalk weight and stalk diameter were relatively strong as were correlations between hand Brix and the lab estimate of Brix. The mean estimates, in general, correlated better with stool measurements than correlations among stool derived measurements.

Correlations between the PROB and the observed number of progeny exceeding the target value were generally very high ( $r > 0.90$ ; Table 7). Thus, the assumption of normality appeared valid. In contrast to the findings of George (1959), the cross standard deviation was not strongly correlated to the cross mean (Table 8). Except for stalk number at Chacahoula, correlations between the cross mean and the PROB were larger than 0.84. This suggested that the additional effort to collect data to estimate the standard deviation and thus be able to calculate the PROB was not necessary. Assuming the PROB was the best estimate of cross worth, correlations within locations among means, standard deviations, and the PROB suggested the mean value was an adequate predictor of cross worth for all traits studied.

Table 2. Means, standard deviations and estimated percentage of cross progeny that will exceed a target value for stalk number, stalk length, stalk diameter and estimated stalk weight.

Cross female x male	Stalk number		Stalk length		Stalk diam.		Est. stalk wt.	
	C <sup>a</sup>	SG	C	SG	C	SG	C	SG
	stool <sup>2</sup>		cm		mm		kg	
US86-011	11.4	7.9	235	193	20	22	0.77	0.73
x	± 6.0	± 5.8	± 24	± 34	± 3	± 3	± 0.25	± 0.28
CP72-370	(30) <sup>b</sup>	(17)	(22)	(3)	(21)	(16)	(22)	(8)
US86-008	8.9	7.8	239	256	20	23	0.74	1.07
x	± 4.4	± 3.8	± 21	± 29	± 3	± 3	± 0.20	± 0.31
CP80-323	(10)	(7)	(24)	(52)	(12)	(26)	(14)	(43)
CP65-357	9.9	10.0	215	217	19	21	0.63	0.80
x	± 3.6	± 5.6	± 21	± 24	± 3	± 3	± 0.24	± 0.29
US86-016	(9)	(27)	(3)	(6)	(10)	(13)	(8)	(3)
CP62-374	9.1	8.2	229	231	20	23	0.74	0.98
x	± 3.2	± 4.9	± 20	± 22	± 3	± 3	± 0.25	± 0.31
US86-016	(4)	(14)	(10)	(15)	(17)	(28)	(18)	(31)
CP79-318	8.6	7.3	240	225	21	23	0.86	0.94
x	± 8.4	± 3.6	± 18	± 23	± 3	± 2	± 0.28	± 0.23
US86-004	(24)	(5)	(22)	(11)	(31)	(21)	(35)	(21)
CP79-318	9.1	8.7	219	233	20	21	0.73	0.86
x	± 4.0	± 8.0	± 27	± 36	± 4	± 4	± 0.29	± 0.30
US86-006	(8)	(28)	(10)	(28)	(24)	(17)	(21)	(18)
US86-004	9.9	7.0	230	231	18	21	0.62	0.80
x	± 4.6	± 4.9	± 26	± 28	± 3	± 3	± 0.20	± 0.21
CP79-318	(15)	(10)	(18)	(21)	(5)	(6)	(4)	(6)
US86-015	9.7	6.1	227	223	19	21	0.64	0.78
x	± 4.6	± 3.2	± 42	± 22	± 3	± 3	± 0.26	± 0.22
CP83-637	(14)	(1)	(27)	(8)	(10)	(8)	(11)	(6)
US86-002	10.1	8.9	221	188	20	20	0.71	0.64
x	± 4.3	± 7.8	± 23	± 39	± 3	± 3	± 0.28	± 0.27
CP73-351	(15)	(28)	(8)	(4)	(17)	(7)	(18)	(3)
US86-002	10.3	6.9	213	192	19	22	0.64	0.73
x	± 4.2	± 4.8	± 23	± 28	± 3	± 3	± 0.23	± 0.27
CP86-659	(15)	(9)	(4)	(1)	(10)	(17)	(8)	(7)
mean	9.7	7.9	227	219	20	22	0.71	0.83
	± 5.0	± 5.5	± 27	± 35	± 3	± 3	± 0.26	± 0.29

<sup>a</sup> C = Chacahoula, SG = St. Gabriel.

<sup>b</sup> The target value for all probabilities was one standard deviation greater than the overall mean.



Table 3. Means, standard deviations and estimated percentage of cross progeny that will exceed a target value for stool weight, hand Brix, pith and tube.

Cross female x male	Stool wt.		Hand Brix		Pith		Tube	
	C <sup>a</sup>	SG	C	SG	C	SG	C	SG
	kg		%					
US86-011	8.56	5.55	18.0	15.5	1.32	1.28	2.60	2.14
x	±4.73	±3.64	±1.8	±0.3	±0.91	±0.70	±1.73	±0.97
CP72-370	(37) <sup>b</sup>	(4)	(10)	(5)	(19)	(21)	(40)	(39)
US86-008	6.41	8.00	19.1	19.0	1.02	1.14	2.50	2.32
x	±2.89	±3.66	±1.8	±1.2	±0.14	±0.53	±1.22	±1.11
CP80-323	(10)	(15)	(26)	(66)	(0)	(9)	(33)	(47)
CP65-357	6.22	8.26	18.6	15.7	1.06	1.06	1.42	1.28
x	±3.34	±5.89	±1.4	±1.4	±0.24	±0.24	±0.70	±0.45
US86-016	(12)	(27)	(13)	(2)	(0)	(0)	(1)	(1)
CP62-374	6.62	8.12	17.9	15.2	1.36	1.30	1.14	1.06
x	±2.82	±5.50	±1.6	±2.2	±0.96	±0.86	±0.40	±0.24
US86-016	(11)	(25)	(7)	(6)	(21)	(26)	(0)	(0)
CP79-318	6.69	6.69	19.2	17.2	1.76	1.42	1.26	1.40
x	±3.58	±3.49	±1.4	±1.5	±1.42	±1.13	±0.66	±0.67
US86-004	(17)	(7)	(22)	(20)	(40)	(35)	(0)	(7)
CP79-318	6.49	7.39	18.7	15.7	1.20	1.06	1.32	1.40
x	±3.62	±8.41	±1.5	±1.5	±0.78	±0.31	±0.77	±0.70
US86-006	(16)	(30)	(13)	(3)	(12)	(1)	(1)	(7)
US86-004	5.90	5.70	19.1	16.8	1.08	1.04	1.86	1.74
x	±2.69	±4.26	±1.5	±1.9	±0.34	±0.20	±1.34	±0.80
CP79-318	(6)	(8)	(21)	(18)	(0)	(0)	(19)	(20)
US86-015	6.08	4.70	17.1	16.1	1.06	1.00	2.44	1.82
x	±3.36	±2.66	±1.7	±1.6	±0.31	±0.00	±1.37	±0.83
CP83-657	(11)	(0)	(3)	(7)	(0)	(0)	(33)	(24)
US86-002	6.89	6.12	18.9	16.7	1.24	1.22	1.72	1.28
x	±3.39	±6.68	±1.5	±2.2	±0.80	±0.76	±1.07	±0.50
CP73-351	(17)	(20)	(18)	(20)	(13)	(20)	(11)	(1)
US86-002	6.62	5.22	18.9	16.7	1.44	1.36	1.84	1.42
x	±3.82	±4.27	±2.0	±2.1	±1.39	±0.85	±1.18	±0.67
CP86-659	(18)	(6)	(18)	(19)	(31)	(28)	(16)	(7)
mean	6.65	6.58	18.5	16.5	1.25	1.19	1.81	1.59
	±3.51	±5.23	±1.7	±2.1	±0.87	±0.66	±1.22	±0.82

<sup>a</sup>C = Chacahoula, SG = St. Gabriel.

<sup>b</sup> The target value for all probabilities equaled the mean plus the standard deviation.

Table 4. Cross progeny mean stalk weight, mean sucrose content and mean Brix.

Cross female x male	Mean stalk wt.		Mean sucrose content		Mean Brix	
	C <sup>a</sup>	SG	C	SG	C	SG
	kg		kg/Mg cane		%	
US86-011 x CP72-370	0.66	0.68	97	88	16.3	15.3
US86-008 x CP80-323	0.72	0.86	98	102	17.0	14.6
CP65-357 x US86-016	0.61	0.82	107	99	17.7	17.0
CP62-374 x US86-016	0.71	0.80	97	98	16.8	15.1
CP79-318 x US86-004	0.78	0.79	101	87	17.0	14.1
CP79-318 x US86-006	0.63	0.78	103	87	17.0	15.7
US86-004 x CP79-318	0.56	0.75	102	84	17.8	14.0
US86-015 x CP83-637	0.66	0.74	92	85	15.9	16.5
US86-002 x CP73-351	0.63	0.63	106	87	17.8	14.2
US86-002 x CP86-659	0.55	0.66	106	85	17.9	16.3
mean	0.65 ±0.07	0.75 ±0.07	101 ±5	90 ±7	17.1 ±0.6	15.6 ±1.0

<sup>a</sup> C = Chacahoula, SG = St. Gabriel.

Table 5. Correlations between Chacahoula and St. Gabriel in cross mean, standard deviation and the probability of elite progeny.

Correlation	Stalk no.	Stalk length	Stalk diam.	Est. stalk wt.	Stool wt.	Hand Brix	Pith	Tube	Stalk wt.	SC <sup>1</sup>	Brix
Mean	0.04 <sup>a</sup>	0.45	0.58	0.43	-0.18	0.58	0.89**	0.90**	0.50	0.02	0.61
SD	-0.33	-0.08	0.25	0.06	-0.40	0.14	0.82**	0.77**	---	---	---
Prob.	-0.22	0.37	0.40	0.26	-0.26	0.70 <sup>*</sup>	0.90**	0.89**	---	---	---

<sup>a</sup> SC - sucrose content.

<sup>\*</sup> P ≤ 0.05 and <sup>\*\*</sup> P ≤ 0.01 that correlations are significantly different from zero.

Table 6. Correlations among traits on a single stool and cross mean basis for two locations.

Trait <sup>a</sup> \\H SG\\	Stalk no.	Stalk length	Stalk diam.	Est. stalk wt.	Stool wt.	Hand Brix	Pith	Tube	Mean stalk wt.	Mean Brix	Mean SC
Stalk no.		0.05 <sup>b</sup> -0.27	-0.22 -0.30	-0.18 -0.33	0.67 0.63	-0.02 -0.23	0.06 -0.13	0.00 0.49	-. -0.56	-. 0.03	-. 0.12
Stalk length	0.18 -0.09		0.25 0.45	0.53 0.67	0.39 0.25	0.20 0.04	-0.04 0.22	0.10 0.32	-. 0.75	-. -0.50	-. -0.62
Stalk diam.	-0.07 -0.06	0.23 0.55		0.94 0.96	0.45 0.51	0.09 0.20	0.00 0.71	0.04 -0.30	-. -0.76	-. -0.23	-. -0.05
Est. stalk wt.	0.00 -0.03	0.61 0.88	0.90 0.87		0.52 0.49	0.13 0.17	0.01 0.66	0.05 -0.16	-. 0.85	-. -0.34	-. -0.23
Stool wt.	0.87 0.71	0.36 0.54	0.30 0.55	0.39 0.66		0.10 0.17	0.03 0.66	0.04 -0.16	-. 0.85	-. -0.34	-. -0.23
Hand Brix	0.06 -0.24	0.35 0.41	0.02 0.30	0.16 0.42	0.11 0.07		-0.04 0.22	-0.01 -0.30	-. -0.06	-. 0.79	-. 0.71
Pith	-0.01 -0.10	-0.02 -0.38	-0.00 0.50	-0.02 0.06	-0.03 -0.03	-0.03 0.06		-0.14 -0.43	-. 0.42	-. 0.03	-. 0.10
Tube	-0.00 -0.37	0.06 0.25	0.06 0.08	0.08 0.18	0.02 -0.26	0.08 0.51	-0.05 -0.24		-. -0.08	-. -0.41	-. -0.48
Mean stalk wt.	-. 0.20	-. 0.89	-. 0.66	-. 0.89	-. 0.75	-. 0.24	-. -0.26	-. 0.10		-. -0.53	-. -0.48
Brix	-. 0.00	-. 0.12	-. 0.01	-. 0.09	-. 0.05	-. 0.84	-. 0.05	-. 0.31	-. 0.02		-. 0.91
Mean Sucrose content (SC)	-. 0.55	-. 0.47	-. 0.56	-. 0.63	-. 0.85	-. 0.19	-. -0.05	-. 0.04	-. 0.68	-. 0.14	

<sup>a</sup> Correlations above the diagonal are for the Chacahoula location, below the diagonal are for the St. Gabriel location.

<sup>b</sup> Upper correlation is on a stool basis, lower correlation is on a cross mean basis. For a stool basis,  $r \geq 0.63$   $p \leq 0.05$ ,  $r \geq 0.76$   $p \leq 0.01$  and for a cross basis,  $r \geq 0.09$   $p \leq 0.05$ ,  $r \geq 0.12$   $p \leq 0.01$  that the correlation is significantly different from zero.

Table 7. Correlations between predicted proportion of a cross exceeding a target and the actual percentage exceeding the same target for each location.

Loca- tion	Stalk no.	Stalk length	Stalk diam.	Est. stalk wt.	Stool wt.	Hand Brix	Pith	Tube
Chac.	0.61	0.97**	0.94**	0.90**	0.92**	0.97**	0.92**	0.96**
St. Gab.	0.82**	1.00**	0.94**	0.98**	0.69*	0.98**	0.91**	0.98**

\*  $P \leq 0.05$ ; \*\*  $P \leq 0.01$ .

Table 8. Correlations among cross mean, standard deviation and the probability exceeding a target value for Chacahoula and St. Gabriel.

Correlation	Stalk no.		Stalk length		Stalk diam.		Est. stalk wt.		Stool wt.		Hand Brix	
	C <sup>a</sup>	SG	C	SG	C	SG	C	SG	C	SG	C	SG
$r_{x, sd}$	-0.07 <sup>b</sup>	-0.30	-0.14	-0.39	0.08	-0.04	0.45	0.34	0.83	0.47	-0.17	-0.44
$r_{x, P}$	0.53	0.89	0.85	0.84	0.95	0.95	0.96	0.95	0.96	0.82	0.91	0.95
$r_{sd, P}$	0.80	0.92	-0.59	0.08	0.74	0.27	0.68	0.58	0.95	0.87	0.19	-0.36

<sup>a</sup> C = Chacahoula, SG = St. Gabriel.

<sup>b</sup> Correlations  $\leq 0.65$  or  $\leq 0.76$  significantly different from zero at the 0.05 and 0.01 level, respectively.

### Appraisal Methodology

A practical appraisal method must consider such things as: the seedling planting arrangement, transplanting logistics, arrangements for the sharing of seed and/or seedlings between testing locations, constraints of manpower and seed availability, and the ease and type of data collection.

The appraisal should ideally be performed over several locations although this may be impractical. The Louisiana LAES and USDA breeding programs each typically screen about 200 crosses per year. The redundancy of crosses planted in a given year is very small, less than 2%. Resource limits would probably constrain cross evaluation in Louisiana to unreplicated tests at each location for experimental crosses. Crosses with a promising evaluation at a one location would apt to be appraised and planted for selection at both locations in subsequent years. All crosses in the seedling stage should be tested each year and its mean value used for evaluation.

The breeding programs of both agencies use a Speedling<sup>TM</sup> system (4) for transplanting seedlings from the greenhouse to the field. The programs typically plant a minimum of two Speedling<sup>TM</sup> trays of progeny from each cross, using one tray to plant each row. The LAES program uses trays that hold 128 seedlings while the USDA uses trays that hold 72 seedlings. Thus, the usual minimum number of seedlings planted of a particular cross is 256 and 144, respectively. Unpublished data by Despradel (LSU master's research) demonstrated that a sample size of 50 individuals from a cross gave a stable estimate of the mean and variance of a cross for all the traits considered in that study. One of the objectives of a cross evaluation system is to minimize resource commitment to untried crosses. Although a minimal number of seedlings could be planted among the regular seedlings to be selected, a separate planting block would minimize the field variability among the experimental crosses and enhance the accuracy of the evaluation. Despradel's study and the logistics of handling and planting the transplanting trays suggests that two trays, each one-quarter filled 128-cell trays and one-half filled 72-cell trays, be planted by each agency (i.e. four and two crosses per tray, respectively). This would place 64 and 72 seedlings per cross in the LAES and USDA evaluation tests, respectively. Considering winter kill and transplanting survival this should provide a minimum yet sufficient number of seedling to evaluate.

The collection of individual stool data requires the demarcating of individual stools. The collection of mean data would simplify data collection by requiring separation of only the beginning stool and an ending stool of each cross. Data such as stalk counts would be obtained from between the two points. An appraisal method could be to determine mean stalk counts of some 50 stools per cross or those available in a cross evaluation block. Time constraints and to avoid working in lodged cane suggests this occur before selection. In Louisiana, single stool selection occurs in early September, a month before the onset of harvest. Stalk samples for weight and sucrose content estimations could be collected from randomly selected stools after selection. The samples could use a pooled sample of stalks, one from each stool, for analysis. The sooner sampling is performed after selection, the better the discernment among crosses for early maturity. Such data could then be used to plan future crosses, for parental evaluation and used to restrict selection to the most promising crosses in the following season.

Crosses are commonly replanted because they have produced elite material in the past, regardless of their percent advancement. A question that arises with these crosses is whether a particular cross is truly elite or does it give exceptional material because large numbers of its progeny were planted and thus the odds of finding superior progeny increased. Cross appraisal based on a mean data base would tend to keep two types of crosses,



those crosses that perform well consistently over years and locations, and those newer crosses that have the potential to perform well but by chance were favored by the recent yearly or local environmental conditions. Good performing, stable crosses are clearly desirable. If the assumption is made that the newest crosses generally come from matings among the newest and most elite genotypes, those crosses that perform well even if unstable have good potential to produce elite genotypes transgressing the parents in performance. Those crosses that subsequently proved unstable would, however, soon be dropped and thus would not unduly dilute the population with genes unfavorable to general adaptation. The overall mean performance value would provide data to base dropping crosses that were productive in past years but were beginning to fail relative to the increasing population mean. Discarding once productive crosses would be based on a replicated and more accurate data base than the current method of percent advancement.

The reliability of using average stool weight or total weight for a number of stools to predict the cane yield potential of a cross remains questionable. Although the magnitude of cross by location interaction seems similar to published heritability estimates for genotypes, additional studies are needed better quantify this point.

There are many options concerning kind of data to collect and how to use it. The input and development of appraisal methodology will be driven by the demonstrated and perceived value of this information.

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## FLOWERING OF HYBRIDS FROM COMMERCIAL SUGARCANE X *SACCHARUM SPONTANEUM* CROSSES

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### ABSTRACT

The wild cane *S. spontaneum* is an important source of genetic variation in sugarcane (*Saccharum* sp.) breeding, but it is difficult to make interspecific crosses because many clones of this species flower earlier than commercial clones. Inheritance information on flowering date in interspecific crosses would be a great benefit to the nobilization program.  $F_1$  progenies of nine crosses of commercial clones x *S. spontaneum* were used to investigate the genetic behavior of flowering date and to estimate its heritability. The  $F_1$  hybrids were obtained from crosses of three commercial clones pollinated with stored pollen of three *S. spontaneum* clones. The  $F_1$  progenies were planted in a randomized complete block design. Flowering data were collected on first ratoon plants under natural field conditions. On average,  $F_1$  progenies flowered approximately 43 days later than *S. spontaneum* parents, and approximately 67 days earlier than their commercial maternal parents. The frequency distribution of flowering date of  $F_1$  progenies was skewed toward the later flowering date with about 4% non-flowering clones. Transmission of early flowering date from *S. spontaneum* to the  $F_1$  progenies was very strong. The regression coefficient of  $F_1$  progenies on midparent was  $b = 0.85$ . The estimated narrow sense heritability was moderate with  $h^2 = 0.24$ . Therefore, selection for flowering date would be moderately effective. Since the majority of the  $F_1$  progenies flowered earlier than the commercial clones, pollen storage and/or photoperiodic treatments are needed to overcome the difficulty of making backcrosses in the course of nobilization.

### INTRODUCTION

Interspecific hybrid sugarcane cultivars, which have almost entirely replaced the noble canes *Saccharum officinarum*, have been derived by hybridization of *S. officinarum* with *S. spontaneum*, *S. sinense*, *S. barberi*, and to some extent *S. robustum* (15, 17, 18). *S. spontaneum* has been the most important species to improve *S. officinarum* for commercial production by improving yielding ability, disease resistance, ratooning ability and adaptability (2, 9, 10, 12). Although there are more than 300 *S. spontaneum* clones in World Collections, only a few clones (mainly Indian and Java forms) appear in the pedigree of modern sugarcane cultivars (12, 15, 17). Many *S. spontaneum* clones flower earlier than do commercial sugarcane cultivars at the Canal Point, Florida location (26° 52' N). Therefore, germplasm of the early flowering wild canes is difficult to utilize in a sugarcane breeding program. Methods of delaying and advancing date of flowering (7, 8) and pollen storage techniques (16) have been used to overcome different dates of flowering. Genetic information on the flowering behavior of interspecific crosses in the  $F_1$  and advanced generations is important to the planning of crossing and selection strategies in a nobilization program.

In commercial sugarcane cultivars, genetic investigations on the intensity of flowering (6) and flowering date (5) have been carried out with  $F_1$  hybrid populations derived parents differing widely in flowering date. The genetic behavior of flowering characteristics appeared to be controlled by a complex polygenic system as suggested earlier by Stevenson (15). The flowering frequency in  $F_1$  progenies from commercial sugarcane cultivars and *S. spontaneum* was less intense than their *S. spontaneum* parent (13). A critical genetic analysis of the date of flowering in interspecific hybrid populations would enhance the utilization of *S. spontaneum* in sugarcane breeding program.

Objectives of this study were to study flowering date of the  $F_1$  populations from crosses between commercial sugarcane cultivars and *S. spontaneum* and to estimate the heritability of this trait.

### MATERIALS AND METHODS

Nine  $F_1$  populations were derived from crosses between three commercial sugarcane cultivars (CP 65-357, CP 80-1763 and CP 80-1902) as females, and each of three *S. spontaneum* clones (SES 275, SES 501 and Holes) as males. Stored pollen of these *S. spontaneum* clones was used to pollinate the male-sterile tassels of the commercial sugarcane cultivars to produce  $F_1$  seed (16). The experiment was established in February 1987 in a randomized complete block design. Each block contained 10 plots and 10  $F_1$  progenies from each cross were planted randomly in each of the 10 plots in a single row, with 1 m between plants in rows and 1.5 m between rows. The six parents also were planted randomly in a single-row plot as checks. A 1 m single stalk cutting from



each of the  $F_1$  progenies and parental clones was used as seedcane to plant in the sub-plot. Due to non-uniform germination after planting, data on date of flowering were collected on the first ratoon crop rather than the plant cane crop. The ratoon crop was started 3 March 1988, when all plants were cut back to ground level. Date of flowering was recorded once 1 to 3 cm of the inflorescence (tassel) of each clone emerged from the flag leaf sheath. Data recorded every Tuesday and Friday from early September 1988 and through late January 1989.

To express flowering date on a quantitative basis, data were recorded as the numbers of days after 3 March 1988 to the day when the first tassel appeared. Nonflowering clones were excluded from the analysis of variance. The original data were transformed by subtracting 200 from the mean to reduce the volume of numbers during the process of computation.

Narrow-sense heritability ( $h^2$ ) was estimated by regressing  $F_1$  mean on midparent flowering date (3, 11). Heritability estimate was also calculated from the variance components (1, 3, 4). Heritability of the flowering date was estimated by  $h_s^2 = 4\sigma_m^2/\sigma_t^2$ ,  $h_d^2 = 4\sigma_f^2/\sigma_t^2$  and  $h_{(d+s)}^2 = 2(\sigma_m^2 + \sigma_f^2)/\sigma_t^2$ , where  $h_s^2$  = estimate of heritability based on male component,  $h_d^2$  = estimate of heritability based on female component,  $h_{(d+s)}^2$  = estimate of heritability based on male and female components,  $\sigma_t^2$  (phenotypic variance) =  $\sigma_m^2 + \sigma_f^2 + \sigma_{mf}^2 + \sigma_w^2$ ,  $\sigma_m^2$  = the variance component due to *S. spontaneum* male parents,  $\sigma_f^2$  = the variance component due to the commercial sugarcane cultivar female parents,  $\sigma_{mf}^2$  = the variance component for male x female interaction and  $\sigma_w^2$  = the variance component of individual plants.

## RESULTS AND DISCUSSION

The *S. spontaneum* clones flowered between early and late September 1988 whereas the commercial sugarcane cultivars flowered between late December 1988 and early January 1989 (Figs. 1 and 2). The difference in flowering date between males and females was approximately 110 days.

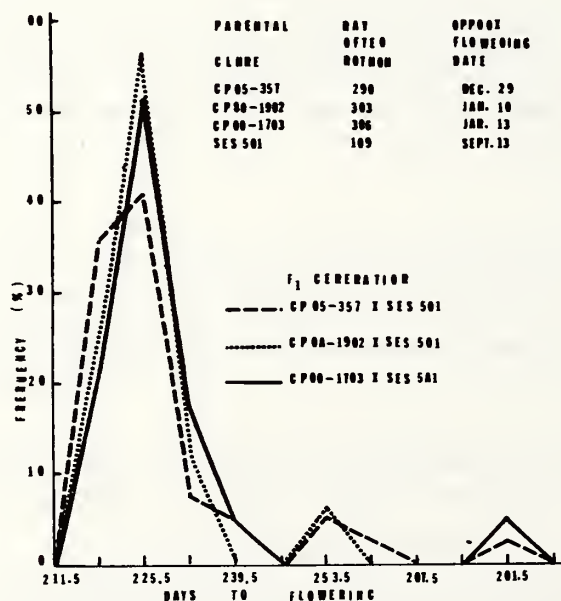


Figure 1. The frequency distribution of flowering date of  $F_1$  populations from crosses between three commercial sugarcane cultivars and one *S. spontaneum* clone.



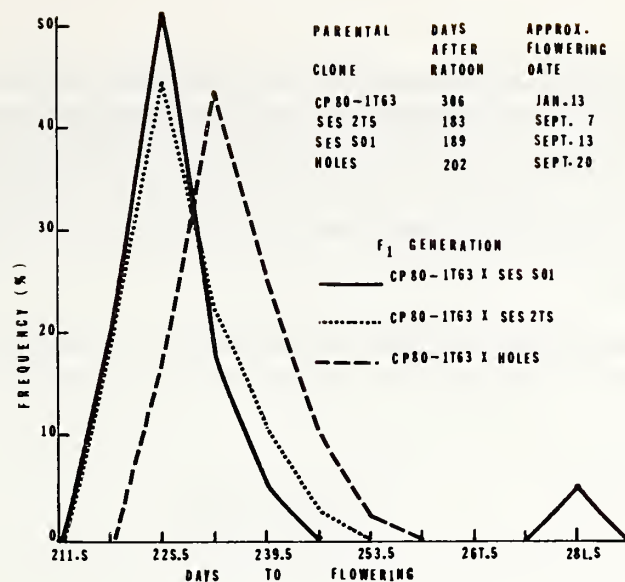


Figure 2. The frequency distribution of flowering date of  $F_1$  populations from crosses between one commercial sugarcane cultivar and three *S. spontaneum* clones.

Analysis of variance indicated that there were no significant differences among commercial sugarcane cultivars as female parents in flowering date, but there were highly significant differences among the *S. spontaneum* as male parents (Table 1). The significant interaction effect between females and males indicated that they did not act independently on the flowering date of the  $F_1$  hybrid plants.

Table 1. Analyses of variance of flowering dates of  $F_1$  plants from crosses between commercial sugarcane cultivars (females) and *S. spontaneum* clones (males).

<u>Analysis of variance of plot means.</u>			
<u>Source</u>	<u>df</u>	<u>Expected mean squares</u>	<u>Mean squares</u>
Replications	3		
Between males (M)	2	$\sigma_e^2 + n_k \sigma_w^2 + r \sigma_{mf}^2 + r f \sigma_m^2$	240.8425**
Between females (F)	2	$\sigma_e^2 + n_k \sigma_w^2 + r \sigma_{mf}^2 + r m \sigma_f^2$	11.8359
M x F interaction	4	$\sigma_e^2 + n_k \sigma_w^2 + r \sigma_{mf}^2$	128.0762**
Error	24	$\sigma_e^2 + n_k \sigma_w^2$	9.7802
<u>Analysis of variance of individuals</u>			
<u>Source</u>	<u>df</u>	<u>Expected mean squares</u>	<u>Mean squares</u>
Between plots	35		
Between individuals,			
Within plots	290	$\sigma_w^2$	119.4200

\*\* Significant F values at 1% level of probability.

r = number of replications

m = number of male parents

f = number of female parents

$$n_k = \frac{1}{rmf} \sum_{hij} \frac{1}{n_{hij}}$$

Flowering of  $F_1$  progeny ranged from 89 to 100% among nine populations (Table 2). No  $F_1$  plant flowered

earlier than its respective *S. spontaneum* male parent, but each of the seven crosses produced few non-flowering  $F_1$  hybrids. The non-flowering  $F_1$  hybrid genotypes might be from recombination between genes from both male and female parents. Among the three *S. spontaneum* male parents, Holes flowered only about one week later than SES 501 and about two weeks later than SES 275, and consistently produced later-flowering  $F_1$  progenies. The mean flowering dates of the  $F_1$  populations indicated that commercial sugarcane cultivars x SES 275 and commercial sugarcane cultivars x SES 501 were significantly different from commercial sugarcane cultivars x Holes (12). There were no significant differences among commercial sugarcane cultivars (female parents) under same *S. spontaneum* (male) parents.

Table 2. Average days to flowering from ratooning and percentages of flowering  $F_1$  plants from nine crosses between three commercial sugarcane cultivars and three *S. spontaneum* clones.

Cross	Average days to flowering from first ratoon <sup>1</sup>	Percentage of flowering plants
CP 65-357 x SES 275	227.3 a *	100
CP 80-1902 x SES 275	229.9 a	89
CP 80-1763 x SES 275	229.1 a	95
CP 65-357 x Holes	235.5 b	94
CP 80-1902 x Holes	237.2 b	100
CP 80-1763 x Holes	235.5 b	97
CP 65-357 x SES 501	226.8 a	92
CP 80-1902 x SES 501	228.5 a	95
CP 80-1763 x SES 501	228.8 a	98

\* Means followed by same letter are not significant at 5% level of probability by Duncan's Multiple Range Test (14).

<sup>1</sup> Plant crop was cut on 3 March 1988.

The frequency distributions were used to further examine the characteristics of  $F_1$  populations regarding the flowering date. Figure 1 shows the distribution of progeny for crosses between the commercial sugarcane cultivars and SES 501. A majority of the  $F_1$  plants flowered at 218 and 232 days. The flowering date of these  $F_1$  populations showed distributions with a strong skewness toward a later flowering date. Frequency distributions of the flowering date of  $F_1$  populations from crosses between CP 80-1763 and three *S. spontaneum* clones (SES 275, SES 501 and Holes) showed that a majority of  $F_1$  progenies from CP 80-1763 x SES 275 and CP 80-1763 x SES 501 flowered approximately two weeks earlier than did a majority of  $F_1$  progenies from CP 80-1763 x Holes, (Fig. 2.) The modes were around 225.5 days for CP 80-1763 x SES 275 and CP 80-1763 x SES 501 and around 232.5 days for CP 80-1763 x Holes. The frequency of late-flowering  $F_1$  hybrids from CP 80-1763 x Holes was much higher than those from the other two crosses, CP 80-1763 x SES 275 or CP 80-1763 x SES 501. The frequency distributions of the flowering date of the  $F_1$  populations indicated that the possibility of bridging the date span of between early and late flowering clones with intermediate as suggested by Moore (7) was very strong. These data suggest that Moore's (7) proposed use of intermediate flowering clones to bridge the date between extremely early and late flowering clones would work reasonably well if large populations and a range of parental clones were used. However, when crosses are desired among early and late-flowering  $F_1$  clones, other techniques such as pollen storage or photoperiod treatments should be considered to overcome the different dates of flowering.

For all crosses, a majority of  $F_1$  progenies were early-flowering like *S. spontaneum*. These distribution characteristics tended to suggest that the early-flowering was partially dominant over the late-flowering. However, there were a few  $F_1$  plants that flowered late, closer to the flowering date of the commercial sugarcane cultivars, suggesting that the inheritance of the flowering response in  $F_1$  hybrids is very complex. Narrow-sense heritability estimate of the flowering date obtained by regressing  $F_1$  population means on mid-parent was  $h^2 = b = 0.85 \pm 0.12$  (Fig. 3). The heritability of flowering date is very high as reported earlier by Roach (11). Based on the estimated regression coefficient, for each day of delay of the midparent flowering date, the average flowering date

of the offsprings would be delayed 0.85 days. The heritability of flowering date estimated from variance components (Table 1) were  $h_e^2 = 0.24 \pm 0.16$ ,  $h_d^2 = 0$  and  $h_{e+d}^2 = 0.12 \pm 0.22$ . These values were much smaller than offspring-midparent regression coefficient. The estimated  $\sigma_f^2$  (variance component due to the female parental effect) was negative; therefore, it was assumed that contribution from female parents to the genetic variance component was zero (4).

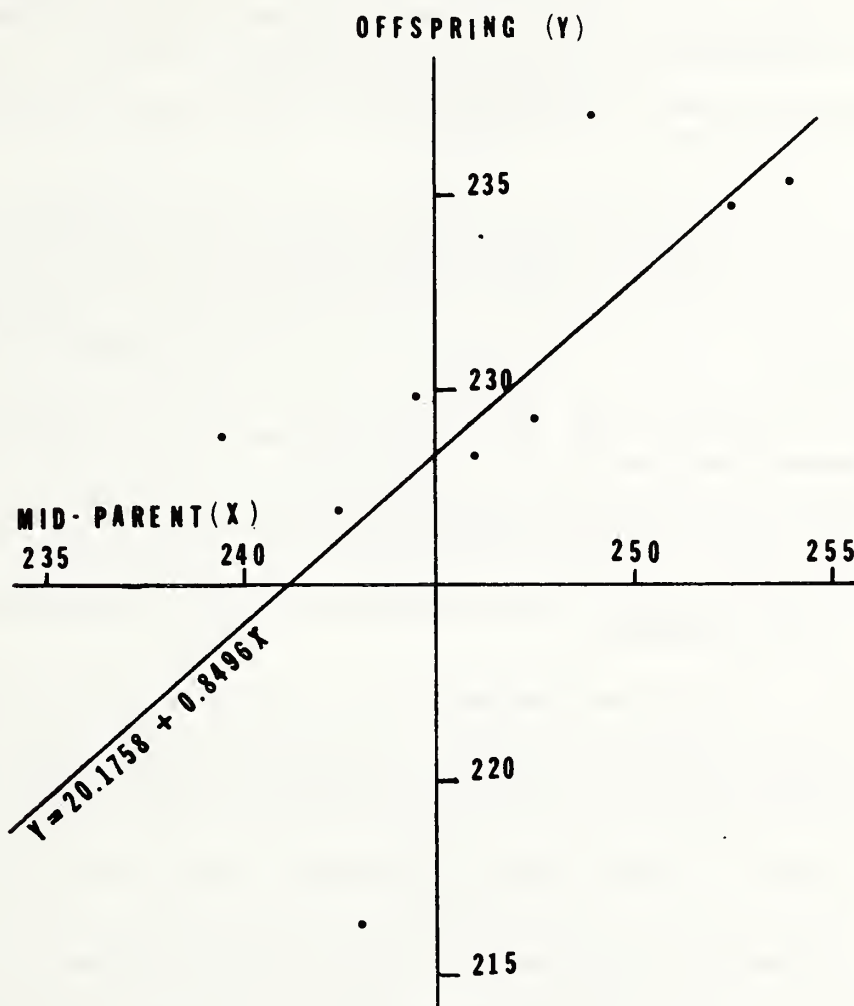


Figure 3. Regression of offspring on mid-parent for the date of flowering in *Saccharum*. Axes indicate flowering date from 3 March 1988.

The success of making crosses between clones with different dates of flowering is important for improvement of sugarcane and would greatly expand the germplasm base of commercial sugarcane cultivars. To fully understand the genetic behavior of the flowering date, information from  $F_2$  and  $BC_1$  populations should also be collected. Knowledge of the genetic behavior of flowering date in sugarcane would help breeders manipulate the flowering date so that progenies with more desirable flowering dates could be obtained.

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## COMPARISON OF CLARIFICATION REAGENTS FOR POLARIZATION ANALYSIS OF SUGARCANE JUICE

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### ABSTRACT

Lead subacetate has been the reagent of choice for clarification for polarization analysis of cane juices and sugars. However, because of health and environmental concerns, current disposal of lead and other heavy metals waste to landfill must cease by August 1990. An alternative reagent, aluminum chloride together with calcium hydroxide, was compared with lead subacetate at the Juice Quality Laboratory of the Sugarcane Research Unit at the Ardoyne Farm, Houma, Louisiana. In a preliminary study conducted in 1988, a paired comparison of 1085 sugarcane juice samples showed that aluminum chloride/calcium hydroxide will successfully clarify fresh and partially deteriorated sugarcane juices. A subsequent study in 1989 on 846 juice samples confirmed these results. The pol readings from the two analyses showed a perfect, linear relationship ( $R^2 = 1.00$ ); however, values from samples with aluminum chloride/calcium hydroxide were slightly lower than those with lead subacetate. A survey of 21 mills in Louisiana showed that 7 mills tried the new procedure in analyses of juice in the core or factory laboratory. In general, all mills were satisfied with the results, although two mills indicated that the new procedure was more time consuming or that the filtrate in some instances was too dark. Thus, aluminum chloride/calcium hydroxide can be used as a substitute for lead subacetate in polarization analyses without loss of precision and reliability or increase in cost of materials; however, time to prepare and process samples may be increased.

### INTRODUCTION

The selection of an appropriate clarifying reagent is one of the most important operations in saccharimetry (2). Rapid filtration and brightness of clarification are factors which must be considered as well as a minimum degree of error. At the turn of the century, Brown stated that alumina cream alone could be used with sugar products of the highest purity. If the products were slightly discolored or if alumina cream was insufficient for clarification he suggested the use of neutral lead acetate solution. If these reagents failed to clarify the solution he then suggested lead subacetate, basic lead nitrate or neutral lead acetate with hypochlorite. In the final analysis, dry lead subacetate gave the best results for sugarcane juice. However, the use of lead subacetate was not permitted by the International Commission for Uniform Methods of Sugar Analysis (ICUMSA) until 1932 because of what was called the volume error. It proved of great value in sugar analysis, routine purity determinations and other control tests in beet and cane factories as well as refineries (12). Since its introduction, lead subacetate has long been the reagent of choice for sugarcane juice clarification for pol measurement.

Due to the health and environmental concerns associated with all lead reagents and other heavy metals, lead subacetate will become increasingly expensive to use (4). In 1990, according to the Resource Conservation and Recovery Act of 1976 and subsequent amendments, current disposal of lead and other heavy metals to landfill must stop. Industries generating less than 1000 kg hazardous waste in a calendar month were brought under Environmental Protection Agency regulations. As a result of this reclassification, the cost of disposal of lead waste will increase dramatically.

Because of the health hazard, environmental concerns and the projected increase in the cost of the use and disposal of lead subacetate, several attempts have been made to find a suitable replacement (3, 4, 5, 6, 10, 13). The sugarbeet industry has led in the replacement of lead salts. European regulatory restrictions and experience with the use of non-toxic reagents including aluminum sulfate, aluminum chloride and aluminum chloride plus calcium hydroxide have been described by Mauch (11), Laursen (8) and Winstrom-Olsen and Pallesin (14) in Subject 9, ICUMSA Proceedings. In the United States, Martin et al. (10), Kolberg (7) and Bichsel and Kysilka (1) studied the effect of aluminum salt clarification on sugarbeet brei for pol and chemical analyses. This research led to the use of an aluminum sulfate method by the California Beet

Growers Association and replacement of lead acetate by aluminum sulfate methods on sugarbeet brei at several other mills.

Seeking alternative clarification reagents for the sugarcane industry, Clarke (5) suggested the use of aluminum sulfate with calcium carbonate for most applications in routine analyses of sugarcane products except raw and refined sugar analysis. The method required the use of powdered charcoal to remove color. Chou (3) found that a combination of suspensions of aluminum chloride and calcium hydroxide was effective; however, his method also used powdered carbon which may prevent its use on sugarcane juice or other products containing a high level of suspended solids. Clarke and Legendre (4) reported that, while powdered carbon may give reproducible results in clarification of high purity materials, the unpredictable adsorption of solids or colloidal material on the carbon introduces a non-reproducible factor that affects the amounts of sugar absorbed by the carbon. Clarke and Bourgeois (6) reported that aluminum chloride hydroxide and powdered calcium hydroxide along with a mixture of bentonite and polymeric flocculants in a ratio of 10:1:2 gave excellent results on sugarcane juice and other process analyses. They stated that the mixing of the three reagents should be made fresh daily as the mixture has a tendency to pack. Further, although the filtration rate was usually faster than with lead reagent, the color was often more yellow.

Many alternative clarifying compounds were tested initially by personnel at Sugar Processing Research, Inc. (4). Sugarcane juice is more difficult to clarify than raw sugar or sugarbeet juice because of suspended solids and polysaccharides. Of all the reagents tested, a method using suspensions of aluminum chloride and calcium hydroxide was most satisfactory; the method was adapted from the sugarbeet brei clarification system of the Swedish Sugar Company (11).

The objectives of this study were to determine if (1) the alternative reagents would satisfactorily clarify a variety of sugarcane juices, and (2) the procedures would give similar polarization values.

#### MATERIALS AND METHODS

The sugarcane Research Unit's juice quality laboratory analyzes 5-10,000 sugarcane samples annually for cane and juice quality estimation. These data are obtained from 5- to 15-stalk samples of normally clean cane harvested from field experiments and brought to the laboratory for analyses. Samples are weighed and the juice is extracted by either a 3-roller sample mill (60%) or a prebreaker/hydraulic press (40%). The 3-roller mill is set to give approximately 50% extraction by a weight of sample with a single crushing. The hydraulic press gives 65-75% extraction with a 1000 g subsample pressed for 2 minutes at 175.7 kg/cm<sup>2</sup> (2500 PSI). Regardless of the method of extraction, approximately 500-1000 ml of juice are collected from each sample, and after a set of 10 is completed, the samples are brought into the juice quality laboratory for analysis. The juice is analyzed for Brix by refractometer and apparent sucrose (pol) by polarization (12).

In the present study, a paired comparison of 1085 and 846 juice samples during the 1988 and 1989 harvest, respectively, was done with the standard clarifying reagent lead subacetate and with aluminum chloride together with calcium hydroxide. All reagents were added in the dry form into the juice.

The procedure used in clarifying juice with aluminum chloride together with calcium hydroxide was as follows (modified from Clarke and Legendre,) (4)<sup>1</sup>:

1. Measure 200 ml juice in graduated cylinder and pour into 400 ml beaker.
2. Place beaker containing juice on magnetic stirrer and add stirring bar.
3. Add 2 g calcium hydroxide powder and stir 1 minute.
4. Add 4 g aluminum chloride, 6-hydrate crystals and stir about 15 seconds. (This is different from the original procedure which called for aluminum chloride powder).
5. Add 1 g (1 teaspoon) filteraid (Analytical grade). Stir for 30 seconds, making sure that all reagents are completely dispersed.
6. Filter solution through a 20 cm RA grade 226, filter paper. Discard first 10 ml; collect 100 ml.
7. Obtain polarization (pol) reading of filtrate in a 100 mm flow-through tube in an automatic saccharimeter/polarimeter.

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<sup>1</sup>It is essential that the calcium hydroxide be added first to neutralize the juice prior to the addition of the aluminum chloride.



Data collected for both lead and aluminum procedures included time required to obtain 100 ml filtrate, color and clarity of filtrate and pol reading. From data collected for Brix, temperature and the two pol readings, the sucrose and purity were calculated for each sample (12). The yield of 96 pol theoretical recoverable sugar (TRS) per ton of cane was then calculated for each sample using equations described by Legendre and Henderson (9). Regression equations were calculated for data from 1988 and 1989 separately and combined, showing the relationship for pol between the two procedures.

## RESULTS AND DISCUSSION

In preliminary studies, Clarke and Legendre (4) found that the aluminum chloride/calcium hydroxide method gave satisfactory clarification on 1083 samples of fresh sugarcane juices and on some partially deteriorated juices. The latter juices are usually difficult to clarify even with lead subacetate, but juices from cane samples taken 18 days following a moderate freeze (-3.3 C or 26 F) were clarified, and their polarization values (pols) read successfully. In the present study, an additional 844 juice samples were clarified using the two methods and, again, the aluminum chloride/calcium hydroxide method gave satisfactory clarification confirming the earlier results. Further, no clarification problems were encountered in severely deteriorated juice (dextran concentration as high as 2984 ppm on Brix using ASI II method) in samples 7 days after a hard freeze (-12.2 C or 10 F). Likewise, there were no problems in clarification as a result of the source of juice, conventional milling with the 3-roller mill or prebreaker/hydraulic press. In general, the clarity of the filtrate using the new method was equal to or better than that using lead. The filtrate was colorless to slightly yellow.

Pol readings, as an average of all samples obtained in both 1988 and 1989 using the two methods, are shown in Figure 1. In both years, the average pol reading using the aluminum chloride/calcium hydroxide method was 0.5 units lower than using the lead procedure. These results are consistent with previous studies comparing aluminum and lead compounds (2, 4, 5, 6).

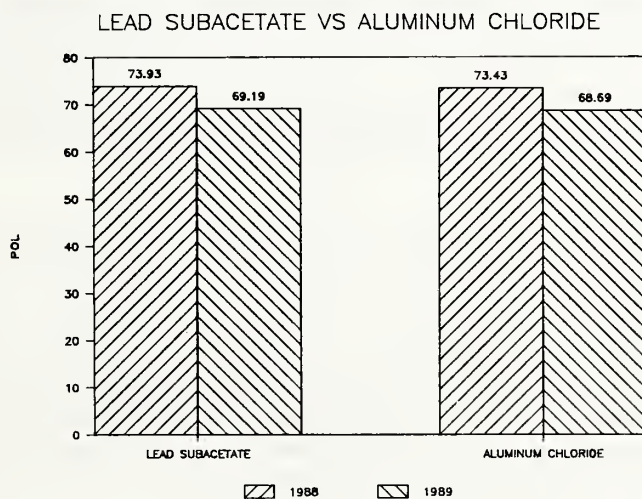


Figure 1. Average pol readings of sugarcane juice samples analyzed in 1988 and 1989 using lead subacetate and aluminum chloride/calcium hydroxide as clarifying reagents.

The average time required to prepare and obtain 100 ml of filtrate using the two methods is shown in Figure 2. In 1988, an additional 5.5 minutes were required for the aluminum chloride/calcium hydroxide method; however, the time was reduced in 1989 by using a better grade of filter paper. Further, for the sake of comparison, 100 ml was collected in the study; however, the volume of filtrate could be reduced to 50 ml or less, depending on polarimeter tube length, which should reduce the overall time to under 4 minutes. However, this method actually required less time on the part of the analyst than a method using slurries of these reagents by requiring no reagent preparation. Additional gains could be made by reducing the stirring time.

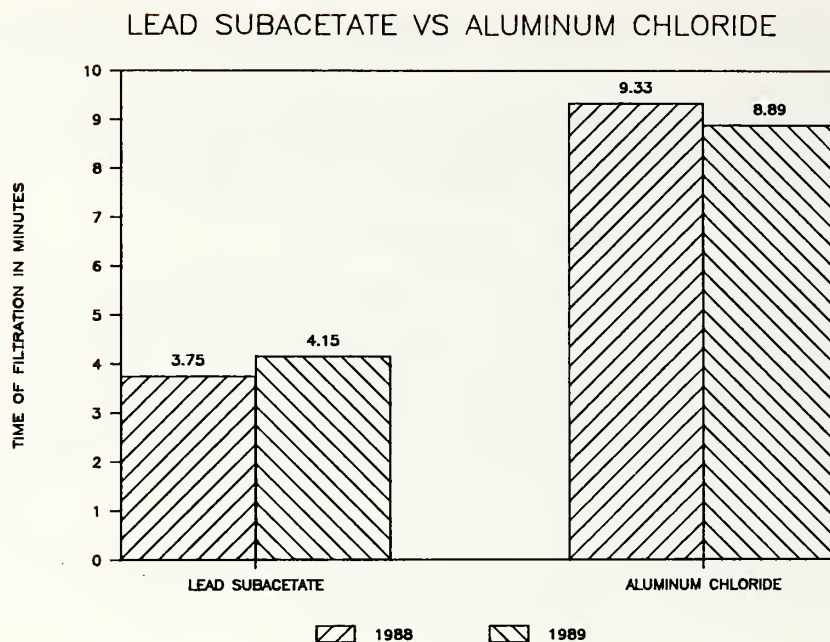


Figure 2. Average time in minutes required to prepare and obtain 100 ml of filtrate using lead subacetate and aluminum chloride/calcium hydroxide as clarifying reagents.

Figure 3 shows the average results in both 1988 and 1989 for pol, sucrose, purity, yield of 96 pol TRS per ton of cane, and time using the aluminum chloride/calcium hydroxide method as a percent of the lead method. The magnitude of the differences between the two methods was essentially the same for the two years with the exception of the time required for the 100 ml of filtrate. The results showed that the aluminum chloride/calcium hydroxide method gave values that equalled approximately 99% of the lead method. However, the results for time were considerably different with the aluminum chloride/calcium hydroxide method requiring 248.8 and 214.2% more time in 1988 and 1989, respectively, than the lead method.

Regression coefficients and coefficients of determination ( $r^2$ ) for pol derived from the aluminum chloride/calcium hydroxide method as a predictor for pol using the lead subacetate method for the years 1988 and 1989, individually and combined, are shown in Table 1. The coefficients of determination of 1.00 indicate a perfect relationship between the dependent variable (pol by lead) and the independent variable (pol by aluminum). Figure 4 shows the best fit lines for the regressions in both 1988 and 1989. The lines match perfectly indicating no difference in the best fit lines for the two years. Because of the excellent relationship in the results for the two methods, the combined regression equation [Pol by lead subacetate = (1.0104 x Pol by aluminum chloride/calcium hydroxide) - 0.2411] may be used to convert the pol reading from the aluminum chloride/calcium hydroxide method to a 'lead method equivalent pol' (a reading that would have been obtained had the familiar lead subacetate method been used).

Other research (4) showed that the amounts of reagents used need not be weighted out if the quantities remain close to what is specified in the procedure. The time required is thus reduced and the reduced time may improve accuracy since complex aluminum hydroxide salts can form with time, decreasing settling speed and affect results. Other studies (4) showed that compared to lead subacetate clarification, aluminum chloride/calcium hydroxide clarification is ineffective in the removal of dextran in sugarcane juice from deteriorated cane. With dextran in the filtrate there is the potential problem of an increased pol (false pol) reading due to the dextran.



# LEAD SUBACETATE VS ALUMINUM CHLORIDE

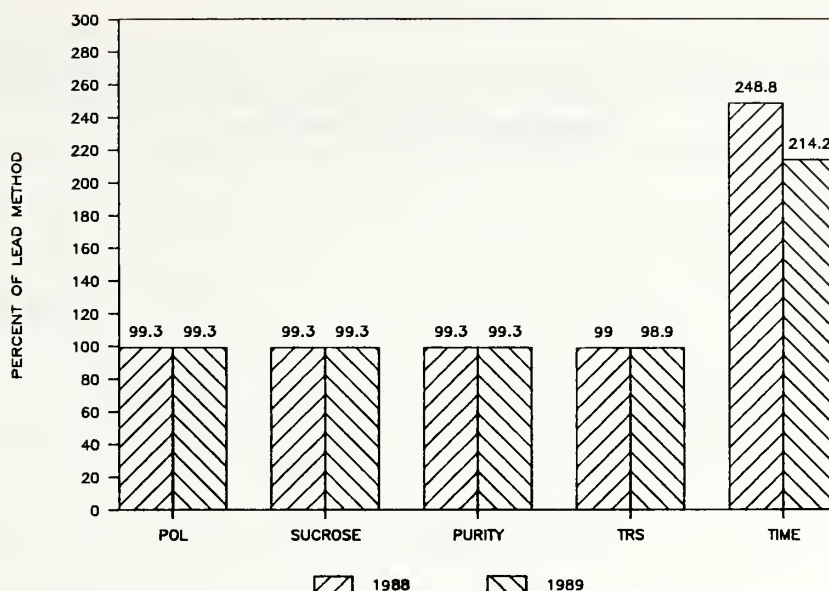


Figure 3. Average results for pol, sucrose, purity, theoretical recoverable sugar (TRS) and time using aluminum chloride/calcium hydroxide reagent as a percent of results obtained with lead subacetate reagent.

Table 1. Regression coefficients and coefficients of determination ( $r^2$ ) for pol derived from aluminum chloride/calcium hydroxide method as a predictor for pol using the lead subacetate method.

Year	Y +	X	a	b	$r^2$
1988	Pol (Pb)	Pol (Al)	-0.3346	1.0113**	1.00
1989	Pol (Pb)	Pol (Al)	-0.2634	1.0112**	1.00
Combined	Pol (Pb)	Pol (Al)	-0.2411	1.0104**	1.00

\*\* Significant at the 1% probability level

+  $Y = a + bX$

A survey of the 21 raw sugar mills operating in Louisiana in 1989 conducted following the harvest season showed that 7 mills tried the aluminum chloride/calcium hydroxide method in analyses of juices in the core or factory laboratory. Specific comments from the survey are shown in Table 2. In general, all users were satisfied with the results, although two mills indicated that the new procedure was more time consuming. Further, technologists at several mills in Louisiana and Florida did their own paired comparison using the two methods and found that the results using the new method were 0.2 - 0.5 units of pol lower than the lead method. As a result, they increased the pol reading by a constant value to equal the results from the lead subacetate method. Others simply used their own regression equation or that reported in the preliminary studies (4).

We find the aluminum chloride/calcium hydroxide method to be environmentally safe and effective in clarifying most sugarcane juices, even those partially deteriorated following a freeze. However, the method may not be suited for badly deteriorated samples since it does not remove dextran. The new procedure gave polarization results which were similar to, but consistently lower than those of lead subacetate. A regression equation can be used to convert pol readings from the new method to those which would have been obtained had lead subacetate been used. Aluminum chloride together with calcium hydroxide can be used in substitution for lead subacetate in polarization analyses without loss of precision and reliability or increase in cost of materials; however, time to prepare and process the samples may be increased.

## LEAD SUBACETATE VS ALUMINUM CHLORIDE

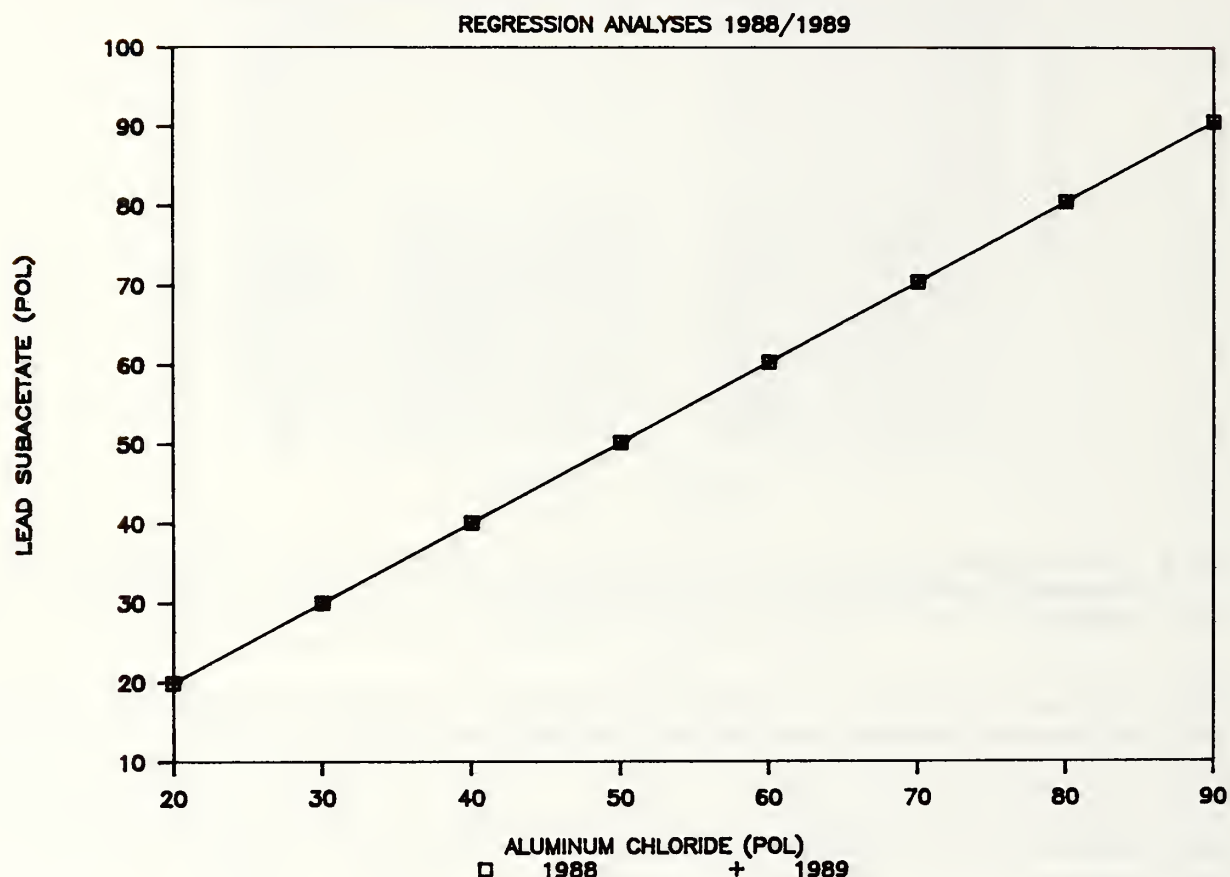


Figure 4. Best fit lines for the regressions in 1988 and 1989 showing the relationship between the two clarifying reagents on pol readings.

Table 2. Comments from commercial users of aluminum chloride/calcium hydroxide method during the 1989 harvest season in Louisiana.

### Clarification with aluminum chloride/calcium hydroxide

#### Comments:

1. Samples were clearer (2)<sup>1</sup>
2. Needed "boost" on saccharimeters for highly colored samples (1)
3. Very simple and just as quick (1)
4. Time consuming and/or cumbersome (2)
5. Results excellent (2)
6. Impossible to use in presence of dextran (1)

<sup>1</sup> Number of responses.

### ACKNOWLEDGEMENTS

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## POST-FREEZE DETERIORATION OF SUGARCANE CULTIVARS IN FLORIDA<sup>1</sup>

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### ABSTRACT

Sugarcane (*Saccharum* spp.) grown in the Everglades Agricultural Area (EAA) of southern Florida is potentially subject to damaging freezing temperatures each year. The objective of this study was to evaluate the post-freeze deterioration of eight sugarcane cultivars following the freeze of 24-26 December 1989. Sugarcane stalks were harvested from a replicated cultivar performance trial, growing as first-ratoon cane, at seven-day intervals beginning 26 December 1989. The cultivars were: CP 70-1133, CP 72-1210, CP 72-2086, CP 75-1553, CP 78-1247, CP 78-2114, CP 80-1557, and CP 80-1827. Crusher juice was analyzed for Brix, polarization, pH, and titratable acidity. Sucrose concentration, purity, and theoretical sugar yield per Mg cane were calculated. Four cultivars (CP 72-1210, CP 72-2086, CP 78-1247, and CP 80-1827) exhibited declining sugar yield beginning two weeks post-freeze. The remaining four cultivars did not show declining sugar yields until three weeks post-freeze. For all eight cultivars, once sugar yield began to decline, a significant linear rate of decline over time was observed. CP 72-1210 demonstrated the slowest rate of decline in sugar yield (2.23 kg sugar Mg<sup>-1</sup> cane week<sup>-1</sup>) while CP 70-1133 showed the most rapid decline (11.65 kg sugar Mg<sup>-1</sup> cane week<sup>-1</sup>). It appears that neither pH nor titratable acidity were satisfactory substitutes for measured sugar yield when assessing juice quality deterioration following a freeze.

### INTRODUCTION

Sugarcane (*Saccharum* spp.) grown in the Everglades Agricultural Area (EAA) of southern Florida is potentially subject to damaging freezing temperatures each year. Freezing temperatures kill young plant-cane shoots and ratoon-crop regrowth. Typically, this type of crop damage results in delayed crop development and/or reduced stalk populations (6). Freezing temperatures can also damage maturing sugarcane prior to harvest. The magnitude of freeze damage to maturing sugarcane is dependent on the severity and duration of freezing temperatures (8,10), cultivar resistance to post-freeze deterioration (1,3,5,6,8,10,11,13,14), and the delay between the freeze event and harvest (1,3,5,7,8,11,13,14).

Pre-harvest freezes have severely damaged EAA sugarcane on three occasions in the past 15 years. The deleterious effects of the January 1977, January 1981, and January 1982 freeze events on maturing sugarcane cultivars have been reported (3,5, and 14, respectively). In December 1989, the EAA sugarcane crop was again exposed to sub-freezing temperatures during the harvest season. The cultivars evaluated for post-freeze deterioration following the 1977, 1981, and 1982 freezes represented 1, 19, and 79%, respectively, of the 1989 sugarcane acreage (4). Cultivars released since 1982 have not been thoroughly evaluated for post-freeze deterioration. Also, since post-freeze deterioration of a given cultivar is dependent on the severity and duration of freezing temperatures (8,10), it is unlikely that the magnitude or rate of deterioration following a freeze would be the same in different years. However, as post-freeze deterioration data is collected over multiple freeze events, the relative rate of deterioration of a given cultivar can be determined. This information may be useful in both post-freeze harvest scheduling and in the development of freeze resistant cultivars.

The objective of this study was to evaluate the post-freeze deterioration of eight sugarcane cultivars following the severe freeze of 24-26 December 1989.

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<sup>1</sup>Florida Agric. Exp. Stn. Journal Series No. R-00863



## MATERIALS AND METHODS

Thirty-eight hours of sub-freezing temperatures ( $\leq 0^{\circ}\text{C}$ ) were recorded at the Everglades Research and Education Center, Belle Glade, FL (TWP:44S, RNG:37E, SEC:10) between December 24 and December 26, 1989 (Figure 1). Beginning December 26, 1989 and continuing at seven day intervals until February 13, 1990, sugarcane stalks were harvested from each plot of a replicated cultivar performance trial growing as first-ratoon cane at Closter Farms (TWP:43S, RNG:37E, SEC:12) in the EAA. The experiment design was a randomized complete block with eight cultivars and four replications. The cultivars were: CP 70-1133, CP 72-1210, CP 72-2086, CP 75-1553, CP 78-1247, CP 78-2114, CP 80-1557, and CP 80-1827. At each sampling date, five randomly selected stalks from each plot were cut at the soil surface and topped at the uppermost hard node. Stalk weight ( $\text{kg stalk}^{-1}$ ) was determined as an average of the five-stalk sample. Stalks were crushed with a three-roller mill at 17.25 MPa roller pressure. The crusher juice was weighed, sub-sampled and analyzed for pH, Brix by laboratory refractometer, and polarization after clarification with calcium hydroxide and aluminum chloride (2). Titratable acidity was determined by titrating 50 ml crusher juice with 0.1N NaOH to a pH of 8.4. Crusher juice sucrose, purity, theoretical sugar yield ( $\text{kg sugar Mg}^{-1}$  cane), and percent juice extraction were calculated. SAS PROC GLM procedures were used for regression analyses (12).

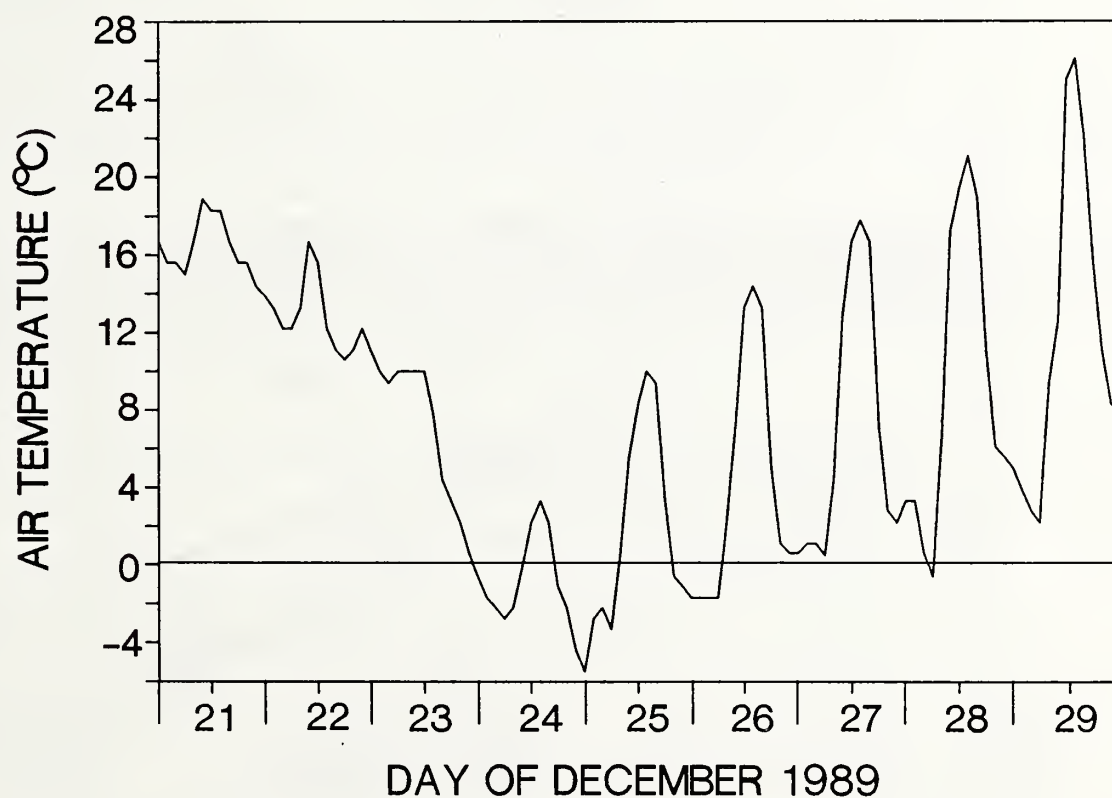


Figure 1. Air temperature recorded at the Everglades Research and Education Center during the freeze event of December 1989.

## RESULTS AND DISCUSSION

Sugar yield (kg sugar Mg<sup>-1</sup> cane) is a critical quality parameter associated with post-freeze deterioration of maturing sugarcane (5,14). Deterioration of severely frozen sugarcane may be evident two days after freezing while deterioration of cane damaged by a moderate freeze may not be evident until two weeks post-freeze (9). The eight cultivars monitored in this study separated into two distinct groups with respect to post-freeze decline in sugar yield. Four cultivars (CP 72-1210, CP 72-2086, CP 78-1247, and CP 80-1827) exhibited declining sugar yield beginning two weeks post-freeze (Figure 2a). Declining sugar yields were not evident until three weeks post-freeze for the other four cultivars (CP 70-1133, CP 75-1553, CP 78-2114, and CP 80-1557) (Figure 2b).

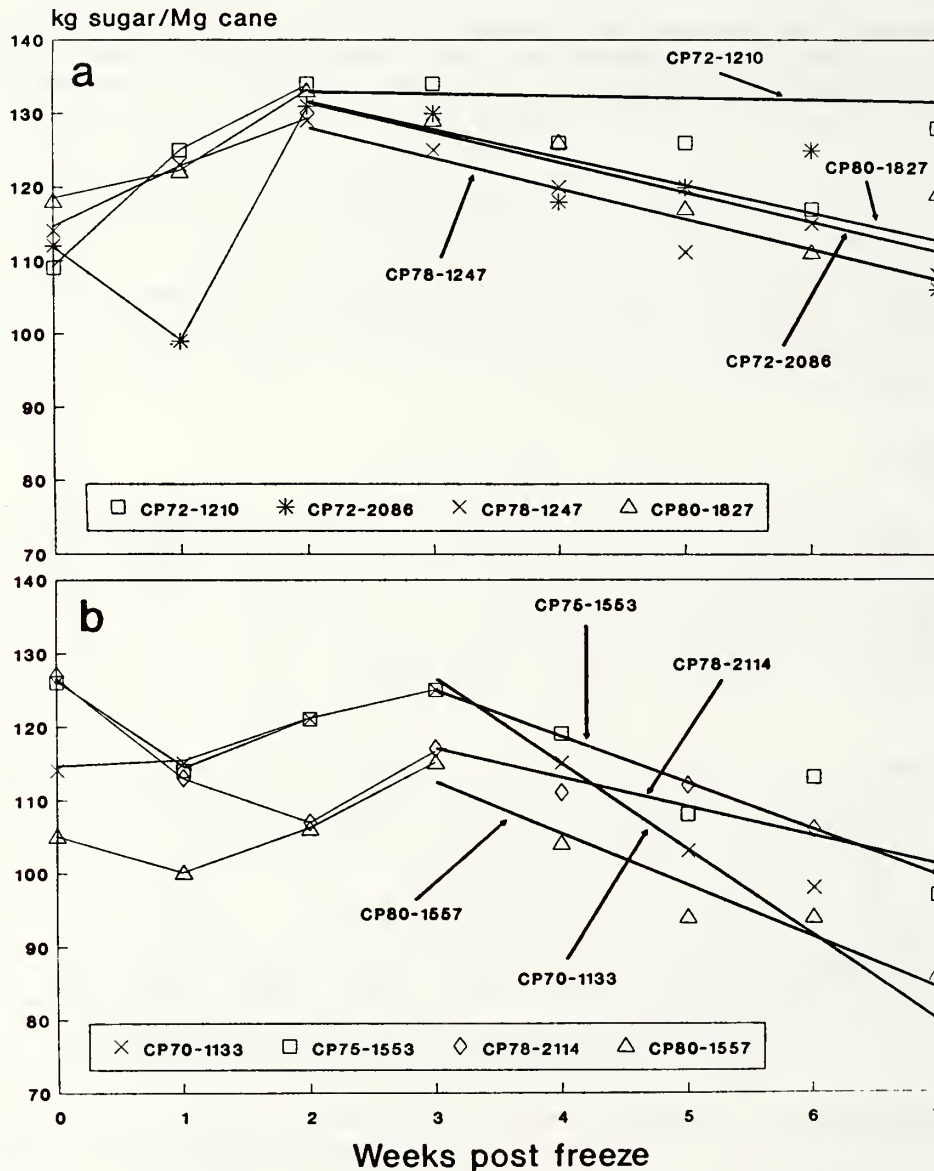


Figure 2. Sugar yield (kg sugar Mg<sup>-1</sup> cane) for sugarcane cultivars following freezing temperatures of December 1989. Sugar yields declined beginning two-weeks (a) and three-weeks (b) post-freeze.

For all eight cultivars, once sugar yield began to decline, a significant ( $P < 0.05$ ) linear rate of decline over time was observed (Table 1). CP 72-1210 demonstrated the slowest rate of decline in sugar yield ( $2.23 \text{ kg sugar Mg}^{-1} \text{ cane week}^{-1}$ ) while the most rapid decline occurred in CP 70-1133 ( $11.65 \text{ kg sugar Mg}^{-1} \text{ cane week}^{-1}$ ).

Table 1. Regression equations for sugar yield ( $Y = \text{kg sugar Mg}^{-1} \text{ cane}$ ) decline over time ( $X = \text{weeks}$ ) for eight cultivars following a pre-harvest freeze.

Cultivar	Time period	Regression equation	Signif.	$r^2$	Standard error of regression coefficient
CP 72-1210	Weeks 2 to 7	$Y = 137.38 - 2.23(X)$	*	0.29	0.82 a
CP 80-1827	"	$Y = 139.06 - 3.70(X)$	*	0.30	1.44 a
CP 72-2086	"	$Y = 139.66 - 3.98(X)$	**	0.41	1.28 a
CP 78-1247	"	$Y = 136.41 - 4.12(X)$	**	0.70	0.64 a
CP 78-2114	Weeks 3 to 7	$Y = 128.89 - 3.96(X)$	*	0.48	1.63 a
CP 75-1553	"	$Y = 144.18 - 6.35(X)$	*	0.53	2.18 ab
CP 80-1557	"	$Y = 133.46 - 6.99(X)$	*	0.24	3.24 ab
CP 70-1133	"	$Y = 161.57 - 11.65(X)$	**	0.81	1.62 b

\*, \*\* Regressions are significant at the 0.05 and 0.01 probability levels, respectively. Standard error of regression coefficient followed by a different letter indicates distinct 95% confidence limits for regression coefficient.

Significant ( $P < 0.05$ ) linear reductions in crusher juice Brix and percent sucrose contributed to juice quality deterioration for all cultivars except CP 80-1557 (Table 2). Juice purity (the ratio of sucrose to Brix) remained unchanged for six cultivars due to relatively equivalent declines in Brix and sucrose (Table 2). For two cultivars (CP 80-1557 and CP 70-1133), significant ( $P < 0.05$ ) linear reductions in juice purity were noted. These two cultivars also had the highest rates of sugar yield decline (Table 1).

Table 2. Regression coefficients and coefficients of determination ( $r^2$ ) for five crusher juice quality characteristics of eight cultivars regressed on time (weeks) following a pre-harvest freeze.

Cultivar	Time period	Regression coefficient				
		Brix	Sucrose	Purity	pH	TA
	weeks					
CP 72-1210	2 to 7	-0.31**	-0.31**	0.00	-0.02	0.13
CP 80-1827	"	-0.29*	-0.44*	-0.01	-0.06*	0.06
CP 72-2086	"	-0.42**	-0.51**	-0.01	-0.11**	0.82*
CP 78-1247	"	-0.58**	-0.58**	0.00	-0.09**	0.15
CP 78-2114	3 to 7	-0.52**	-0.53*	-0.01	0.01	0.09
CP 75-1553	"	-0.44**	-0.73**	-0.02	-0.08*	0.70**
CP 80-1557	"	-0.24	-0.72	-0.03*	-0.11	0.21
CP 70-1133	"	-0.87**	-1.39**	-0.04**	-0.17**	0.67**

Table 2. Continued

Cultivar	Time period	$r^2$				
		Brix	Sucrose	Purity	pH	TA
	weeks					
CP 72-1210	2 to 7	0.33	0.34	0.03	0.25	0.28
CP 80-1827	"	0.27	0.30	0.25	0.36	0.57
CP 72-2086	"	0.67	0.50	0.15	0.49	0.36
CP 78-1247	"	0.62	0.72	0.07	0.81	0.49
CP 78-2114	3 to 7	0.61	0.52	0.35	0.18	0.34
CP 75-1553	"	0.63	0.54	0.53	0.54	0.59
CP 80-1557	"	0.22	0.24	0.26	0.33	0.07
CP 70-1133	"	0.74	0.80	0.74	0.91	0.82

\*, \*\* Regression significant at the 0.05 and 0.01 probability levels, respectively.

TA = Titratable acidity

After a freeze, juice acidification due to the evolution of  $H^+$  during the accelerated hydrolysis of sucrose to glucose and fructose can be quantified by juice pH or titratable acidity. Titratable acidity has been shown to be negatively correlated with Brix, sucrose, purity, and sugar yield (13). While all cultivars demonstrated trends for reduced crusher juice pH following the freeze, only five cultivars had significant ( $P < 0.05$ ) linear reductions over time (Table 2). Of the five cultivars exhibiting significant reductions in juice pH, only three cultivars also exhibited significant ( $P < 0.05$ ) increases in titratable acidity (Table 2). Changes in juice pH and titratable acidity are indirect measurements of post-freeze deterioration. However, it appears that neither pH nor titratable acidity accurately measured the degree of post-freeze deterioration.

Evaluation of sugarcane tolerance to freezing temperatures ideally should include measurements of both sugarcane biomass yield and sugar yield over time (5). The stalk weight and juice extraction data presented in Table 3 was based on a relatively small five-stalk sample. There were no significant ( $P > 0.05$ ) changes in stalk weight over the sampling period. The  $r^2$  values for stalk weight and juice extraction were low, indicating that the length of time post-freeze did not explain a large proportion of the variation in stalk weight or juice extraction.

Table 3. Regression coefficients and coefficients of determination ( $r^2$ ) for stalk weight and % crusher juice extraction of eight cultivars regressed on time (weeks) following a pre-harvest freeze.

Cultivar	Time Period	Regression Coefficient		$r^2$	
		Stalk weight	Juice extraction	Stalk Weight	Juice Extraction
	weeks				
CP 72-1210	2 to 7	0.02	0.01*	0.27	0.49
CP 80-1827	"	0.00	0.00	0.22	0.27
CP 72-2086	"	0.00	0.01**	0.10	0.49
CP 78-1247	"	0.01	0.01	0.42	0.49
CP 78-2114	3 to 7	-0.01	0.00	0.41	0.10
CP 75-1553	"	-0.02	0.01	0.16	0.36
CP 80-1557	"	-0.07	0.00	0.21	0.27
CP 70-1133	"	-0.04	0.00	0.65	0.04

\*, \*\* Regression significant at the 0.05 and 0.01 probability levels, respectively.



The data suggest that the eight commercial sugarcane cultivars evaluated will not show evidence of deterioration for two to three weeks following a freeze event similar in intensity and duration as the freeze of 24-26 December 1989. However, it is important that juice quality monitoring begin immediately following the freeze event in order to establish a baseline value (time=0) against which future juice quality data can be compared. It appeared that neither pH nor titratable acidity were satisfactory substitutes for measured sugar yield for assessment of juice quality deterioration following a freeze.

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## ULTRAFILTRATION AS AN ALTERNATIVE TO CHEMICAL CLARIFICATION IN CANE JUICE POLARIZATION ANALYSES

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### ABSTRACT

A commercially available patented ultrafiltration device was exhaustively tested during the 1989-90 crop at United States Sugar Corporation's two Florida raw sugar factories. It was found that ultrafiltration yields clear juice samples suitable for direct polarization analyses without the use of chemical clarification agents. The ultrafiltration equipment is rugged, compact, simple to maintain, and easily operated by the regular juice chemists at the factory. Based on 1145 comparisons of ultrafiltration and the conventional lead subacetate clarification and on 928 comparisons of ultrafiltration and a clarification procedure using a combination of lime and aluminum chloride, polarization results for the ultrafiltered juices were very strongly correlated with polarization results for the same juices clarified with lead subacetate or with lime and aluminum chloride.

While diluted molasses may be easily ultrafiltered it was found that the resulting permeates were too dark for polarization in normal polarimeters. A combination of a strong anion exchange resin and activated carbon was found effective for decolorization of these materials either with or without prior ultrafiltration. The pol of the resulting decolorized molasses was strongly correlated with the pol of lead-treated molasses.

### INTRODUCTION

For the last several years, the sugar industry has been exploring alternatives to the use of lead salts in clarifying and decolorizing juices and other process samples for polarization analyses (2,3,4). It has become increasingly difficult and expensive to deal with the sizeable quantities of hazardous waste generated when using lead salts in the control laboratory and landfilling of lead-containing waste is prohibited after August 1990.

Drawing on the experience of the beet industry (8,10,11) which has dealt with this problem very effectively, the cane industry has been turning to the use of nontoxic aluminum-based reagents. In comparison with lead subacetate, they produce slow-filtering, highly colored filtrates and may require multiple reagent addition and shaking steps. In addition, dextran is only partially removed by the aluminum procedure while lead removes nearly all dextran (1).

In early 1990, we learned of an instrument employing ultrafiltration techniques that was being used successfully to purify viscous, dirty biological fluids such as cell cultures, fermentation broths, etc. We arranged a demonstration of the instrument to determine how it would work for clarifying cane juice samples prior to pol analysis. Preliminary test with this equipment indicated that a very dirty crusher juice needed to be initially screened to remove bagacillo but otherwise was easily clarified by the instrument. The instrument was then tested for a three-month period to further investigate its applicability to juice purification. This period included the last two months of the 1989-90 crop when both of the U. S. Sugar Corporation mills were dealing with the effects of severe December 24-25 freezes and processing some very poor quality juices. The instrument was used to analyze 1145 crusher juices in parallel with the dry lead subacetate procedure and 928 juices in parallel with the aluminum chloride procedure as published by Clarke and Legendre (1).

### MATERIALS AND METHODS

The instrument utilized in this study to provide ultrafiltered juices was the Benchmark Rotary Biofiltration System marketed by Membrex, Inc. (Garfield NJ). The instrument consists of an electronics module, a magnetic drive assembly, and a rotary separation unit (Figure 1). The membrane is bonded to a plastic cylinder which is rotated inside another cylinder of the appropriate dimensions required to generate the Taylor-Couette vortices (Figure 2). which keep the membrane free from fouling. The membrane used, which is a proprietary item, is a highly hydrophilic modified polyacrylonitrile and has a molecular weight cutoff of 100,000. A number of other membrane types are available, but the 100,000 molecular weight cutoff polyacrylonitrile appears best for this application based on the results of limited comparative tests so far conducted. In operation, the instrument runs continuously at 2500 rpm and a peristaltic pump provides the 6-8 psi driving force for the separation. About 200 ml of juice was required to flush the previous juice

from the system before the permeate pol became constant. The retentate stream was run to waste during this period and then turned to the recycle mode while the actual pol sample was collected from the permeate port directly into a 100 mm polarization tube. The polarization readings so obtained were multiplied by 2 for comparison to lead subacetate polarization numbers.

### Attaching Membrane Cartridge to Drive Assembly

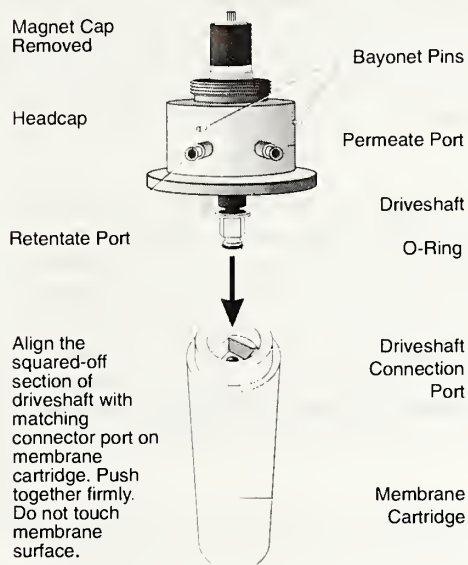


Figure 1. Rotary separation unit.

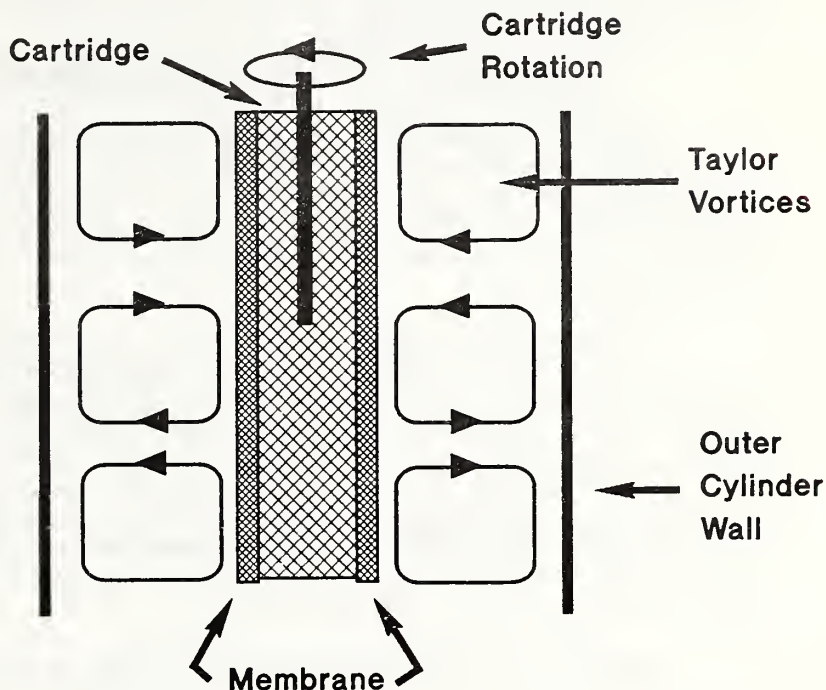


Figure 2. Taylor-Couette vortices preventing fouling of membrane.

Routine maintenance consisted of flushing in place with distilled water and dilute (0.1N) sodium hydroxide solution every 9 hr. This kept the membrane clean, and no real decrease in flux was noted between cleanings.

For comparison, subsamples of the same juices subjected to ultrafiltration were also clarified with lead subacetate or with a combination of lime, aluminum chloride, and filter aid. For the lead clarification, about 3-4 g of dry basic lead acetate (minimum 33% PbO, 70-73% Pb) were added to 150 ml of crusher juice using a calibrated scoop. The mixture was shaken to dissolve lead and then filtered through Reeve-Angel 226 paper. The polarization of the clear filtrate was determined in a Rudolph Autopol IIs automatic polarimeter (Rudolph Research, Flanders, NJ) using a 200 mm tube.

For the aluminum clarification, about 2.5-3 g of powdered calcium hydroxide (Fisher C-97) were added to 150 ml of crusher juice, and the mixture was shaken for 30 sec. Then, about 4-5 g of aluminum chloride hexahydrate (Baker 0498-01) were added, and the mixture was shaken for a further 30 sec. A teaspoon of filter aid (Dicalite Speed Plus) was added, and the whole was filtered through Reeve-Angel 226 paper. The polarization of the clear filtrate was determined in the Rudolph automatic polarimeter using 100 mm tube. The readings so obtained were multiplied by 2 for comparison with the lead subacetate numbers.

Molasses was diluted 1:1 (w/w) with distilled water, then further diluted 26 g to 200 ml. This solution was ultrafiltrated using the same conditions used for the crusher juices and then read in a 200 mm tube in the Rudolph Autopol. For resin and carbon treatment, 12 g of IRA-402 resin (Rohm-Haas, Philadelphia, PA) dried to a moisture content of 25%, 3 g of G-60 carbon (American Norit, Jacksonville, FL)



and 3 g of laboratory standard grade filter aid (Manville Corp., Lompoc, CA) were added to 100 ml of the final molasses dilution prior to reading pol in a 200 mm tube. The pol so obtained was multiplied by 4 in each of the aforementioned cases.

Alternatively, 8 ml of 54°Bx lead subacetate was added to 26 g of the 1:1(w/w) diluted molasses, and the whole was brought to 200 ml. Fifty ml of this dilute solution were then acidified with 5 cm<sup>3</sup> of 0.05N acetic acid. The pol of this solution was determined in a 200 mm tube, and the result was multiplied by 4.4 for comparison to the other methods.

## RESULTS AND DISCUSSION

While ultrafiltration is not new and is used on a commercial scale in other industries, it has not yet been applied successfully to sugar processing. The main problems involve membrane fouling and an accompanying decrease in the rate at which the purified product is produced. While several workers (5,7,12) have investigated ultrafiltration applications in the sugar industry and concluded that the process has potential, there has not been enough equipment development to bridge the gap between research and commercial application.

A recently developed ultrafiltration device (9) utilizes a novel method of preventing membrane fouling. The membrane is bonded to a cylinder which is rotated rapidly within a second closed cylinder of the appropriate dimensions to generate turbulence sufficient to continuously "scrub" the membrane surface clean. While the principle can be applied on a large scale, a laboratory-scale unit with 200 cm<sup>2</sup> membrane area and overall dimensions requiring a minimum (about 2-3 sq ft) of bench space is the subject of this investigation. This unit was used to clarify crusher juice samples obtained directly from the laboratory sample line with no preparation other than screening to eliminate the larger pieces of bagacillo. This was done by simply fitting a slightly inclined 100 mesh screen to the top of the sample container while the juice was collected. The permeate from the ultrafiltration unit was collected directly into a polarimeter tube, and the entire process took 3-4 minutes per sample.

Based on 1145 comparisons of the ultrafiltration procedure and the lead subacetate procedure, a regression equation (Eqn 1) relating pol of lead-clarified juice to pol of ultrafiltered juice was developed.

$$\text{(Eqn 1) Lead pol} = 0.9692 \text{ ultrafiltration pol} + 2.48$$

Juice polys ranged from less than 30 to about 80. The excellent correlation obtained ( $r^2 = .9942$ ) indicated the conversion of ultrafiltration results to lead results was very reliable. The 95% confidence limits for the conversion were  $\pm 1.16$  units of pol at the Clewiston mill. The agreement of actual lead subacetate pol values with predicted values is shown graphically in Figures 3 and 4, which show the lowest 50% and the highest 50% of juice pol data from the Clewiston mill. Bryant mill data (Figure 5) were similar except that the prediction was better, with a 95% confidence interval of just  $\pm 0.74$ .

The instrument handled poor quality juices and good quality juices equally well, and the good correlation with lead subacetate results was independent of juice quality. While the membranes are relatively expensive at about \$140 each, they were found to be capable of handling several hundred juice samples without fouling, thus making the cost per sample quite reasonable. Preliminary testing also indicated that the removal of dextran as judged by the haze analysis is essentially complete (Table 1), thus avoiding the problem of false pol associated with high dextran levels in juices from deteriorated cane.

Based on 928 comparisons of ultrafiltration and aluminum data, a second regression equation (Eqn 2) was developed relating the pol of aluminum-clarified juice to the pol of ultrafiltered juice.

$$\text{(Eqn 2) Aluminum pol} = 0.987 \text{ ultrafiltration pol} + 0.77$$

Again the excellent correlation obtained ( $r_2 = .991$ ) indicated the interconversion of the two types of data to be very reliable. The Clewiston results (Figure 6) are typical and have a 95% confidence interval of  $\pm 1.02$  units of pol for the prediction of aluminum pol from ultrafiltration pol.



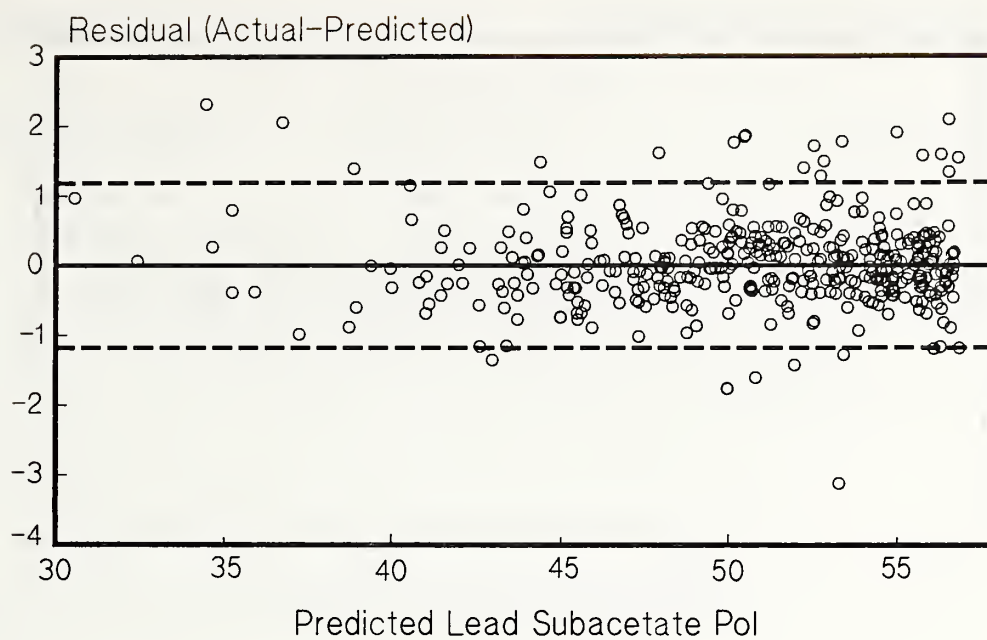


Figure 3. Prediction of lead subacetate pol from ultrafiltration pol. Lowest 50% of results from the Clewiston Mill.

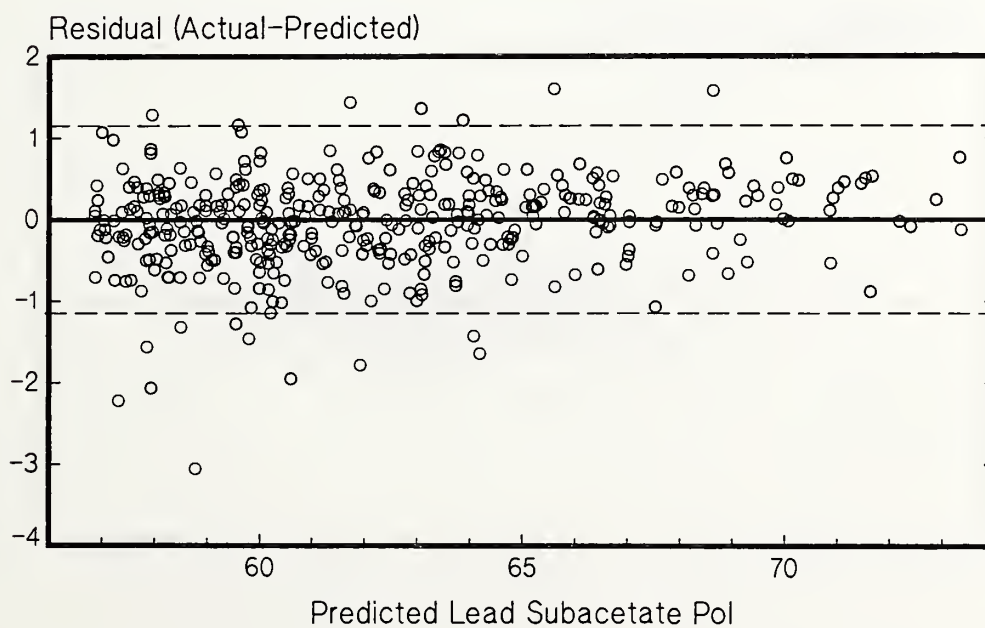


Figure 4. Prediction of lead subacetate pol from ultrafiltration pol. Highest 50% of results from the Clewiston Mill.

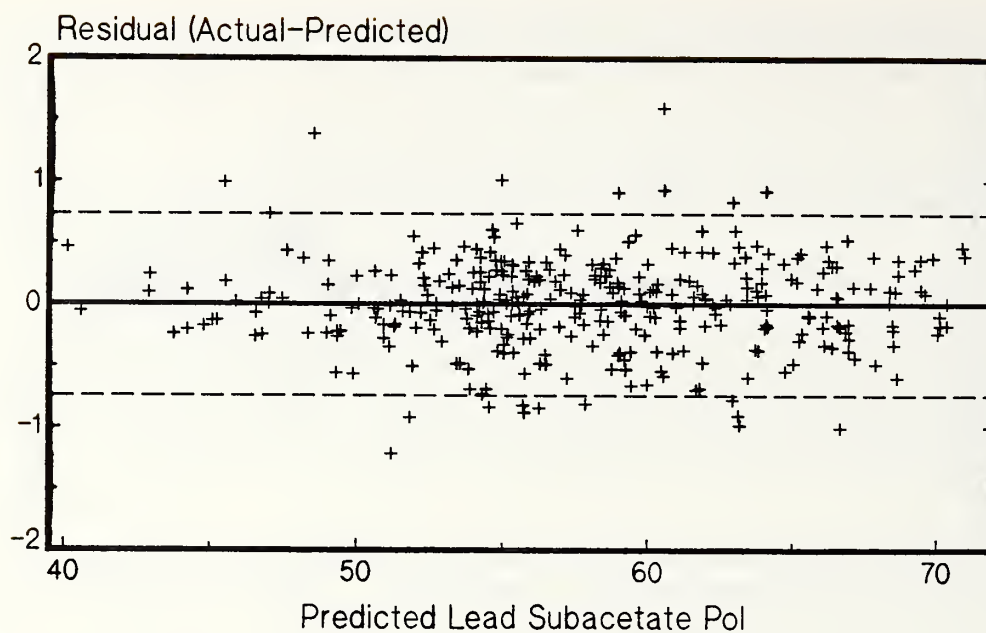


Figure 5. Prediction of lead subacetate pol from ultrafiltration pol. Bryant Mill results.

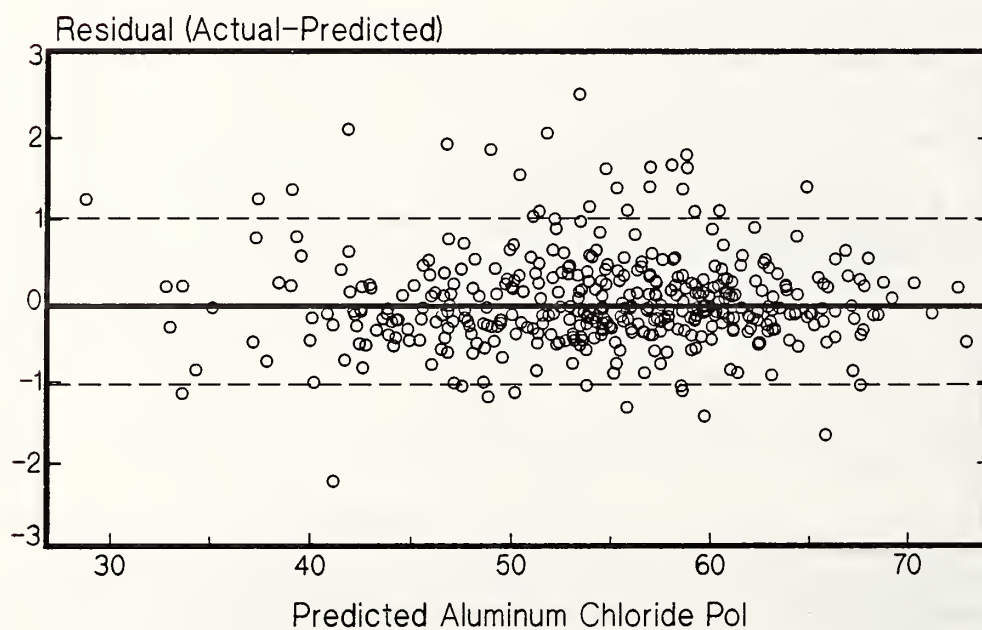


Figure 6. Prediction of aluminum chloride pol from ultrafiltration pol. Results from the Clewiston Mill.

Table 1. Dextran removal from cane crusher juice by the ultrafiltration procedure.

		Dextran (ppm on Brix)	
	Before Ultrafiltration	After Ultrafiltration	% Removal
Juice #1	2583	00	100
Juice #2	9178	56	99.4

We were also interested in pol analyses on the other factory streams, the most difficult of which is probably molasses. While the instrument handles diluted molasses very nicely and produces a clear permeate, the color level of the permeate is beyond the capability of the conventional polarimeter. Some possible solutions to this problem are decolorizing the permeate with activated carbon and a strong anion exchange resin (10), the use of an infrared polarimeter less dependent on solution color (6), or the use of a short pathlength high angular resolution polarimeter such as that described by Chou (4). Preliminary testing with the resin and carbon treatment both alone and in conjunction with ultrafiltration indicated this procedure targets both neutral and charged colorant molecules and is quite effective.

Results on 38 weekly final molasses composites covering the entire 1989-90 crop at both of our mills (Figure 7) indicated that the decolorization works very well when reagent quantities are adjusted correctly and resin moisture is controlled at 25%. The lead subacetate pol and the resin/carbon pol are related by equation (3).

$$\text{(Eqn 3) Lead pol} = 1.0059 (\text{resin/carbon pol}) + 4.11 \quad r^2 = 0.962$$

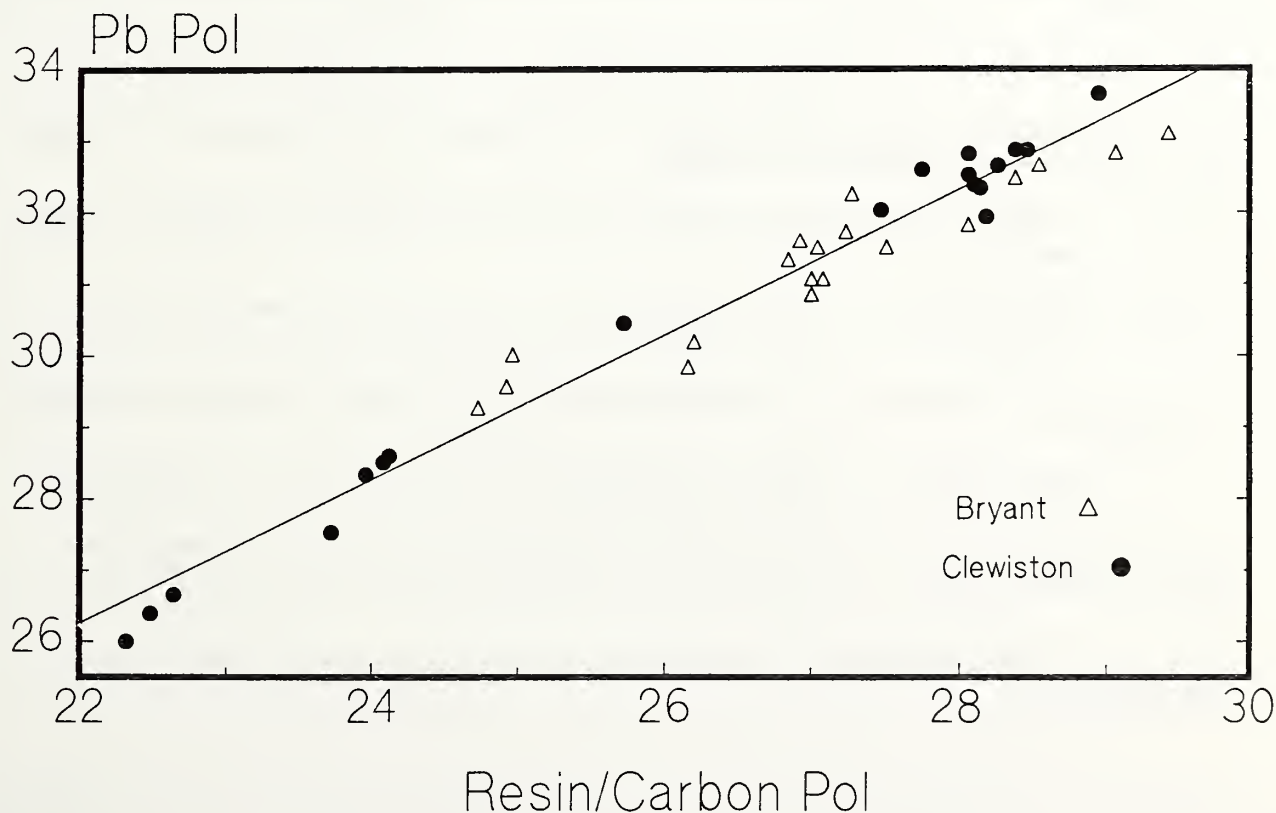


Figure 7. Prediction of lead subacetate polarization of final molasses from resin/carbon polarization.

Ultrafiltration prior to treatment with resin and carbon did not dramatically affect the pol results, which were always several points lower than with lead subacetate clarification. This pol difference was not really unexpected due to the fact that the impurities from the cane and those produced in process end up in a concentrated form in the molasses. Lead subacetate, anion exchange resin, and activated carbon all react with these materials and alter the pol.

### SUMMARY AND CONCLUSIONS

A detailed study of the relationships among the crusher juice pol readings obtained using lead subacetate, aluminum chloride and lime, and ultrafiltration methods for clarification was conducted during the 1989-90 crop at United States Sugar Corporations's two Florida raw sugar factories. The Membrex Rotary Biofiltration System produced clear juice samples which were free of dextran and which could be read directly in a conventional polarimeter. The pol so obtained was very highly correlated with the pol obtained using lead subacetate clarification or aluminum chloride and lime clarification. Regression equations relating the pol of ultrafiltered samples to the pol of lead subacetate-clarified samples and to the pol of samples clarified with lime and aluminum chloride allow the conversion of ultrafiltration pol data to lead-equivalent or aluminum-equivalent pol data. In continuous operation, the ultrafiltration unit was found to be trouble-free and easily operated by regular juice chemists. Membranes were found to be capable of several hundred separations, making the cost per sample quite reasonable. Very dark materials like molasses are not amenable to this approach without additional treatment to remove the high color persisting in the permeates. A combination of a strong anion exchange resin and activated carbon was found to be effective in removing color from dilute molasses solution either or after ultrafiltration. The pol of the sample clarified by resin and carbon was highly correlated with the pol of the same sample clarified with lead subacetate, and a regression equation was developed allowing the pols of molasses samples clarified by resin and carbon to be expressed as lead-equivalent pols.

### ACKNOWLEDGEMENTS

The authors are indebted to Dr. E. C. Watson for performing statistical evaluations and regression analyses on mill trial data.

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## DEXTRAN ANALYSIS - A COMPARISON OF METHODS

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### ABSTRACT

Commercial sugar producers are assessed yearly penalties in millions of dollars for excessive levels of dextran. These penalties are based upon dextran values in raw sugar as determined by the Haze Test. Questions have been raised about the specificity and reliability of this commercially accepted analytical method. We compared this procedure with four experimental tests for determining dextran; an enzymatic procedure, two antibodies based procedures and a gel chromatography procedure. An evaluation of the Haze test relative to these methods is presented.

### INTRODUCTION

For many years, there has been an active interest in developing alternative methods for the detection of dextran. The Haze method<sup>5</sup> has been, and still is, the standard method for levying dextran penalties on raw sugar. This procedure is based upon alcohol precipitation of polysaccharides and measurement of the resulting turbidity. At the Audubon Sugar Institute we have tested a number of methods of dextran analysis. They vary from enzymatic analysis, to molecular weight separation to antigen antibody reactions.

The ASI II method<sup>7</sup> is an enzyme based procedure. This method involves the precipitation of all polysaccharides with alcohol, and then uses dextranase to convert dextran to glucose. The amount of glucose in the end product is determined by reducing sugar analysis<sup>6</sup>. Gel Permeation Chromatography<sup>8</sup> (GPC) is based upon a chromatographic separation by molecular size. The high molecular weight polymers (dextran) elute first, then the low molecular weight polymers followed by sugars and salts. The peak areas are measured using a refractive index detector. Monoclonal and polyclonal antibody based analyses were conducted using specifically prepared reagents. The monoclonal antibodies were prepared against T-2000, two million molecular weight dextrans (Pharmacia). The polyclonal antibody was prepared against a complex of bovine serum albumin and dextran T-2000. The reaction of the antibody with dextran produces a turbidity which is measured using a nephelometer<sup>1</sup>. The object of this study was to compare these methods as to their correlation with Haze values obtained on raw sugar samples.

### EXPERIMENTAL

#### Standard Curve Preparation

Standard curves were prepared using dextran T-2000 (Pharmacia) made up in solutions of 40 Brix raw sugar. Two sets of standards were prepared. One was prepared from untreated commercial raw sugar and the other was from the same raw sugar which had polysaccharides removed by ultrafiltration through a 10,000 cut-off membrane (Pellicon-Millipore Corp.). The same sets of standards were used for calibration of all the different analyses. The raw sugar was an A strike sugar produced at the Audubon Sugar Institute. The initial dextran level in this raw sugar solution was determined by the Haze (390 MAU) and ASI II (546 ppm). After passage through the ultrafilter these values were 0 MAU and 80 ppm respectively.

#### Analytical Procedures

Analyses were conducted on raw sugars obtained from Louisiana sugar mills. All analyses were done in triplicate. We restricted ourselves to raw sugars that contained less than 500 MAU dextran by the Haze method. Because of the large dilution required by the antibody based methods for high dextran samples, we felt that lower levels, requiring a smaller dilution, would be less susceptible to error.

The Haze test was carried out by the method originally described by Keniry<sup>5</sup> and then modified by Amstar Corp (Oct 1981). The GPC procedure was as described by Saska and Oubrahim<sup>8</sup> (1987) and the ASI II procedure was done as described by Sarkar and Day<sup>7</sup> (1985).

The polyclonal antibodies were obtained from Pharmacia (Uppsala, Sweden) as produced for C. Goodacre (Tate and Lyle). The monoclonal antibodies were prepared by Dr. Myron Leon, Dept. of Immunology, Wayne State Medical School, Detroit Michigan. The procedure for using the polyclonal antibody was as described by Goodacre and Martin<sup>3</sup> (1981). The method used with the monoclonal antibody was as described by Clarke<sup>1</sup> (1989).

## RESULTS

### Variation in Analysis, Haze, GPC and ASI II due to Presence of Native Sugar Cane Polysaccharides

Individual standard curves for each method, using treated and untreated sugars are shown in Figures 1 through 3. Each standard curve has an excellent correlation coefficient. However, when one compares standard analyses prepared with untreated versus treated sugars, the Haze shows higher, the GPC lower and the ASI II no differences between analyses. A plot of the differences in standard curves for the three methods is shown in Figure 4. Only the ASI II procedure was unaffected by the presence of high molecular weight polymers in the sugars. The Haze analyses showed non-linear increases in the amounts of dextran detected in the presence of sugar cane polymers. Since this method was affected by the degree of aggregation of the polymers, it is possible that materials present in sugar enhanced aggregation, producing the differences observed in the standard curves. The alternative is that these are true values for dextran and the values obtained after the removal of polysaccharides are invalid as aggregation is inconsistent when the dextran levels are low. The GPC method produced values for standards prepared with the treated sugars that were higher than those for the untreated sugars. It is possible that high molecular weight polymers produced a high background that masked true dextran values with this method.

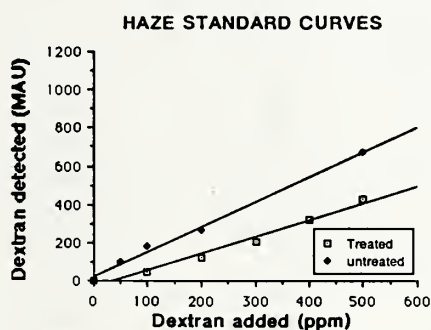


Figure 1. Curves for standards prepared with untreated and treated sugars analyzed by the Haze method.

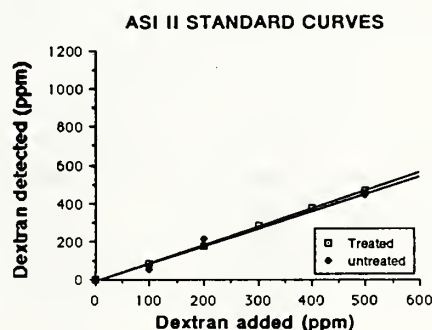


Figure 2. Curves for the standards prepared with untreated and treated sugars analyzed by the ASI II method.

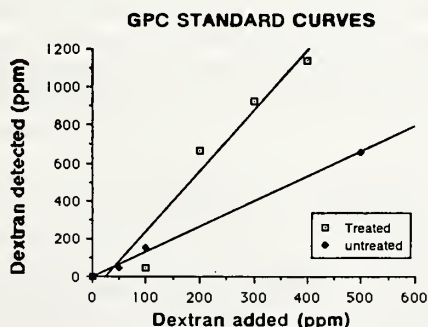


Figure 3. Curves for standards prepared with untreated and treated sugars analyzed by the GPC method.

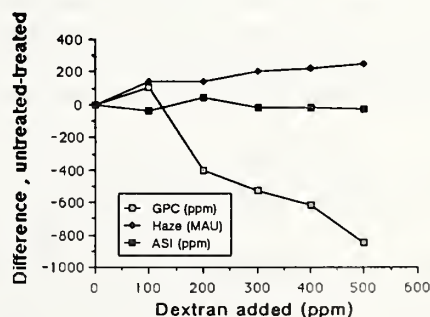


Figure 4. Difference in the standard curves between the untreated and treated sugars. The Haze test is shown as the difference in MAU, the ASI and the GPC methods as the difference in ppm.

Table 1. Correlation coefficients for standard curves, various analyses.

METHOD	CORRELATION COEFFICIENT
Haze	0.9953
Haze (treated sugar)	0.9901
ASI II	0.9991
ASI II (treated sugar)	0.9995
GPC	0.9995
GPC (treated sugar)	0.9995

### Comparison of Methods of Analysis on Raw Sugar

The dextran analyses by five different methods of 10 raw sugar samples are shown in Table 2. It is immediately obvious that none of the various methods were in close agreement with all the others. Although each method is consistent within itself it was impossible to compare cross analyses. Even those methods which are based on similar principles; i.e. the two antibody based methods show wide variations in values for the same sugar.

Table 2. Dextran values for sugars. Analysis By The Different Methods

Sugar	Haze*	ASI II	GPC	Monoclonal Antibody	Polyclonal Antibody
	(ppm)				
1	167	356	243	248	355
2	384	577	531	445	479
3	384	602	413	458	418
4	481	559	557	615	405
5	409	461	623	244	357
6	269	479	364	285	408
7	418	559	664	284	367
8	512	676	546	485	500
9	48	184	374	197	289
10	409	461	610	379	388

\*MAU converted to ppm from a calibration curve, results are reported as ppm

The correlation coefficients for the sugar analyses are shown in Table 3. The Haze method was the only method to show at least a 95% correlation with all of the other methods. The ASI II had the best agreement with the Haze (99.9%) and Polyclonal methods (99.0%) and showed a good correlation (95%) with the Monoclonal Antibody method. The Polyclonal and Monoclonal Antibody methods showed at least a 95% correlation with the Haze, ASI II and each other. The GPC had the lowest correlation with the other methods, with an 80% correlation with Polyclonal and ASI II and no correlation with the monoclonal method.

Table 3. Correlation coefficients-various methods.

Method	Haze	Monoclonal Antibody	Polyclonal Antibody	ASI II	GPC
Haze	1.0000	0.7140	0.7520	0.9040	0.7494
Monó	0.7140	1.0000	0.7005	0.7226	0.3004
Poly	0.7520	0.7005	1.0000	0.8450	0.4537
ASI II	0.9040	0.7226	0.8450	1.0000	0.4909
GPC	0.7494	0.3004	0.4537	0.4909	1.0000



## CONCLUSIONS

Each available method for analyzing dextran is based upon different physical or chemical principles. The Haze test and ASI II separate dextrans from sugar by alcohol precipitation. The Haze test is a non-specific assay that detects non-starch polysaccharides and non-dextrans<sup>2</sup>. The amounts of these polymers which can be detected will vary depending on both their initial concentrations in sugar and the care which is taken with the alcohol precipitation. This method also is not quantitative for dextrans below 150,000 MW. The ASI II method is sensitive for both high and low molecular weight dextrans. It is minimally affected by other polysaccharides in sugars as its specificity is for  $\alpha$  1-6 linkages and it is not dependent upon selective alcohol precipitation. However at low concentrations of dextrans, as measured by Haze (300 ppm), the percentage of  $\alpha$  1-6 linkages can be as low as 60% of the total linkages in the dextran and may affect the accuracy of this method. The percentage of these linkages will increase to 90% at 5500 ppm by Haze<sup>4</sup>.

Gel Permeation Chromatography relies on separation of polymers by molecular size. With large polymers such as dextran the sensitivity of the separation is low. Two peaks, one of high molecular weight and one of low molecular weight are detected by the GPC analysis. Both peaks contain dextran but the low molecular weight peak also includes non-dextran components.

The antigen-antibody procedures are based on detection of  $\alpha$  1-6 linkages. These methods are sensitive for very low concentrations of dextran. However these methods require a certain minimum size of dextran before the antibody reaction can be detected. They detect the dextrans that were used as antigens in preparing the antibodies. Some question arises as to what is actually detected when the antibody is prepared against protein-dextran conjugates, such as BSA-dextran, because antibodies can detect differences in conformations of molecules. The Monoclonal Antibody method seemed to be more specific than the Polyclonal method, and like the Haze was quantitative for dextrans above 150,000 MW.

For routine sugar analysis the Haze test was perfectly satisfactory. It is both reliable and repeatable, but like all the other dextran methods it is not necessarily accurate. One should not use Haze values as an absolute measure for the amount of dextran present in a raw sugar sample as it is both affected by the presence of other polymers in the sugar and it does not reliably detect small dextran molecules. In terms of ease of use and a wider applicability to sugar samples the antibody based methods show the most promise. From the current selection of methods available a laboratory or factory must choose the method convenient for them and use that exclusively for their dextran determinations in order to compare the relative differences or problems encountered.

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## **AGRICULTURAL ABSTRACTS**

### **Sugarcane Varietal Development for the Irrigated, Alkaline Soils of South Texas**

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Inactive since its demise in the 1920s, the Texas sugarcane industry began its renaissance in 1960 with the planting of the first variety trials at the Texas A&M station in Weslaco. During the following 30 years of harvesting variety trials, 218 varieties have been evaluated and 19 varieties have been adopted for commercial production. A data bank constructed with all of the Texas A&M replicated variety trial results showed that extremes of cane yield ranged from 16 to 112 tca, sugar per ton ranged from 4.85 to 13.44 percent and sugar yield ranged from 1.2 to 7.2 tsa.

New candidates for replicated trials come from foreign imports, selections from Florida and Louisiana programs, and from the local seedling selection program based on crosses made at Canal Point, Florida and Baton Rouge, Louisiana. With the exception of the still-dominant variety Nco310, foreign introductions are the poorest source of new varieties. Environmental factors in variety performance include adaptability to soil type, tolerance to salt, chopper harvesters, and resistance to rust, smut, mosaic, and the Mexican rice borer.

### **Flood-Tolerance in the Canal Point Sugarcane Breeding Population**

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Periodic flooding is common in many sugarcane growing regions. In Florida, possible water management schemes may result in land, currently used for growing sugarcane, being flooded or under high water table. This study was conducted to evaluate a large number of sugarcane clones for flood-tolerance, and to estimate the heritability of flood-tolerance in a representative sample of the Canal Point breeding population. A total of 156 clones from six families were planted in a flood treatment and a control. Each clonal plot was replicated three times per treatment; the study was conducted for two years. Each year clones were continuously flooded for approximately five to six months. Whole plots were cut and weighed, and samples were taken for milling and juice analysis. Treatments were different ( $P$  is less than 0.01) for cane yield Mg/ha and sugar yield Mg/ha, but did not differ for Brix ( $P=0.20$ ) or kg sugar per Mg cane. Clones interacted ( $P$  is less than 0.01) with treatments and years for cane and sugar yield. In the flooded treatment, clones had a range of cane and sugar yield from about 20 percent to 70 percent of their respective yield in the control treatment.

### **Cross By Location Interaction in Sugarcane Appraisal**

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The effectiveness of a selection program is limited by the quality of the initial unselected genotypes. Thus, appraising the potential of a cross to produce superior progeny is important. Questions concerning types of data to collect and the need for replication across environments are essentially unanswered for sugarcane.

In 1989, 10 crosses were made among 15 parents at Houma, Louisiana. Fifty first-ratoon stools from each cross were evaluated at Houma and St. Gabriel, Louisiana. Data were collected on stalk number per stool, stalk diameter, stalk length, hand Brix (hand refractometer), and a rating for pith and tube. Mean stalk weight and sucrose concentration were also determined from two 25-stalk per stool, from each cross. Means, standard deviations, and the probability of exceeding a target value (PROB) were calculated. The PROB assumed a normal distribution that was estimated by calculating a Z statistic and finding the associated probability where  $Z = (\text{mean} - \text{target}) / \text{SD}$ . Mean was the cross mean, target was an acceptable threshold and SD was the cross standard deviation. Results indicated a strong cross by location interaction for the estimated stalk weight (based on length and diameter), and little interaction for stalk length, stalk diameter, Brix, pith, or tube. Correlations between locations were poor except for pith ( $r = 0.89$ ), tube ( $R = 0.90$ ), Brix ( $r = 0.58$ ) and stalk diameter ( $r = 0.58$ ). Correlations between the PROB and the observed number of progeny exceeding the target value were very high ( $r = 0.61$  to  $1.00$ ), thus the assumption of normality appeared valid. Assuming the PROB was the best estimate of cross potential, correlations within locations among means, SD and the PROB suggested the mean value was an adequate predictor of cross worth.

The results of this study show that the use of mean data would simplify data collection procedures. A tenable application of these results might be to determine mean stalk counts from 50 stools per cross before selection, then determine mean stalk weight and sucrose by taking one stalk per stool. Data should ideally be determined from several locations but could also be obtained from all crosses in the single-stool stage at one location over years. Sampling should be done soon after selection to better evaluate crosses for early maturity. Such data could then be used to plan future crosses and for parental evaluation. The results could also be used to restrict selection to the most promising crosses in the following season.

#### **Methods to Control Environmental Heterogeneity in Unreplicated Testing in the Louisiana Sugarcane Variety Development Program**

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Early stages of clonal selection in the Louisiana Variety Development Program (LSVDP) test large numbers of genotypes for commercial variety potential. Resource demands limit evaluation to unreplicated tests. Such testing confounds the environmental effects with genotypic effects. Appraising such a large number of genotypes limits the amount of objective data that can be collected.

A study was initiated to test the effectiveness of the modified augmented design to control environmental effects in unreplicated clonal tests. Initial selection stages of the Louisiana Variety Development Program select promising genotypes from unreplicated trials until the number of promising genotypes has been reduced to a manageable number for replicated testing. Selections from seedlings are planted in the first-clonal tests. Selections from the first-clonal tests are planted into the second-clonal tests. Data from clones are collected through at least the first ratoon crop from each test.

In this study, stalk counts, diameter, and height for 618 experimental clones and the corresponding checks were collected from a population in first-clonal ratoon and second-clonal, plant cane stages. A juice analysis for sucrose, purity, and Brix was performed on 260 of these clones and all checks.

In clonally-propagated crops, correlations between stages of testing should be perfect if environmental effects did not exist. Deviation from a perfect correlation is an indication of confounded environmental effects. Use of the augmented design improved the correlation of sucrose yield and cane yield between the first-clonal and second-clonal stages. Correlations of stalk weight and stalk length were minimally improved while correlations of stalk number and stalk diameter were slightly weaker using the adjustment method. The correlation of sugar content was not affected by the adjustment method. The

improved correlations of sucrose and cane yield suggest the augmented design adjustments were removing some of the environmental error in the unreplicated estimates of genotypic worth.



**The Effect of Hybridization on Some Quantitative  
Characters in Crosses of Sugarcane Cultivars  
*Saccharum spontaneum***

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Nine crosses between three sugarcane cultivars (females) and three *S. spontaneum* clones (males) were used to study the genetic behavior of quantitative characters and to estimate the variances caused by genetic differences between female and male parents for characters in the  $F_1$  generation. Characters studied included three morphological traits (leaf length, leaf width, and stalk diameter) and three juice quality traits (Brix, percent sucrose, and percent purity). Both the frequency distributions and coefficients of variation of all six characters indicated that the  $F_1$  progenies were more variable than the parents. The variance attributable to genetic differences between female parents was significant for stalk diameter and Brix, while the variance caused by genetic differences between male parents was highly significant for leaf width, stalk diameter, Brix, percent sucrose, and percent purity. The variance resulting from interaction of genotypes of male and female parents was significant for the performance of all characters except stalk diameter. Some cross combinations between commercial cultivars and *S. spontaneum* produced a higher frequency of superior  $F_1$  hybrids than did other cross combinations. Therefore, the choice of parents and cross combinations should be considered in the utilization of *S. spontaneum* germplasm in a sugarcane breeding program.

**Performance of the Sugarcane Variety LCP82-089  
in Replicated Yield Trials in Louisiana**

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The sugarcane variety LCP82-089 is a selection from the progeny of the cross CP52-68 x CP72-370. The cross was made in 1977 at the USDA facility in Canal Point, Florida. Seedlings were planted, selected and advanced at St. Gabriel Research Station, St. Gabriel, Louisiana by personnel of the Louisiana, "L" Variety Development Program; thus the prefix "LCP."

LCP82-089 was grown at 13 outfield variety trials locations in Louisiana from 1987 through 1989, where it was compared to commercial varieties CP65-357, CP70-321, CP74-383 and CP 79-318. Results from 131 plant cane, 98 first ratoon and 55 second ratoon observations indicate that LCP82-089 compares favorably to the commercial varieties in yield and sugar content in both heavy-and light-textured soils. Observations indicate LCP82-089 is well adapted to mechanical harvesting.

LCP82-089 can be classified as smut-resistant and moderately resistant to the sugarcane borer. It appears moderately susceptible to, but tolerant of sugarcane mosaic virus.

**The Effect of Intrarow Spacing and the Utility of  
Best Linear Unbiased Predictors in Sugarcane Cross Appraisal**

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A quick, accurate, and practical method for appraising a cross's potential to produce elite clones is needed. The current empirical method uses the percent of the originally planted seedlings that are advanced to later stages of the selection program. It requires four to five years and is of questionable accuracy. It was hypothesized that increasing the intrarow spacing may increase the variability of certain sugarcane traits, specifically stalk number. A study was designed to investigate the effect of intrarow spacing on cross



evaluations, and examine types of statistics and their utility in evaluating different sugarcane yield components.

Fifteen crosses among 23 parents were made. One-hundred-twenty progeny from each cross were evaluated in plant cane seedlings at the St. Gabriel Research Station in fall, 1989. Sixty progeny from each cross were grown at normal and double intrarow spacings (41 and 82 cm, respectively). Stalk number per stool, stalk diameter, stalk length, Brix (hand refractometer), and ratings for vigor, pith, and tube were collected. Stalk and stool weight were estimated from the length and diameter. Means, standard deviations, and the probability of exceeding a target value (PROB) were calculated. The PROB assumed a normal distribution. It was estimated by calculating a Z statistic and using the probability associated with it where  $Z = (\text{mean-target})/\text{SD}$ . Mean was the cross mean, target was an acceptable threshold, and SD was the standard deviation of the cross. Mixed model analysis was also performed to calculate best linear unbiased predictors (BLUP) for the crosses. The BLUP method adjusts the cross values for environmental variability and takes into account additive genetic information from related crosses. The BLUPs should be the best indicators of future performance of these crosses and are equivalent to selection indices adjusted for environmental effects.

Crosses differed in their mean and variability in all traits. Cross by spacing effects were significant for mean stalk number, stalk weight, and stool weight. Cross variance was not, however, affected by spacing nor did it show cross by spacing interaction for any trait. Thus there was little indication that increasing intrarow spacing would increase ability to discern differences among clones within a family.

This study was performed on plant cane seedlings. Single stool selection in Louisiana is performed on first ratoon seedlings to select for winter hardiness and to allow plants to reach sufficient size for easy evaluation. In 1989 the seedlings were not well developed and hindered data collection. It is therefore not recommended to collect data on plant cane seedlings in Louisiana.

In this study PROBs were considered the best indicator of a cross's performance. In theory the BLUPs should be the best indicator of the future performance of a cross. The mean was strongly correlated to both the PROB and BLUP estimates for the crosses. Assuming plant cane data is indicative of first ratoon data, this suggested a mean value for a cross should sufficiently indicate the potential of a cross to produce elite progeny. The gathering of only mean data could sufficiently simplify data collection to adequately evaluate 250 crosses per year as in the Louisiana Sugarcane Variety Development Program..

**Influence of Soil Temperature, Moisture, and  
Inoculum Concentration on Pathogenicity of *Metarhizium  
anisopliae* to the Sugarcane Grub *Ligyris subtropicus***

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The white grub *Ligyris subtropicus* (Blatchley) has been identified as the grub species of primary economic importance to Florida sugarcane. *Metarhizium anisopliae*, an entomopathogenic fungus, has been isolated from *L. subtropicus* cadavers recovered from commercial Florida sugarcane fields, verifying its natural occurrence. Research was conducted using fumigated soil under controlled environmental conditions to quantify the influence of soil temperature, soil moisture, and inoculum concentrations on pathogenicity of this fungus to *L. subtropicus*.

Pathogenicity was examined at six soil temperatures ranging from 16°C to 31°C. Mortality due to *M. anisopliae* was observed at all temperatures of 25°C and above. With respect to soil moisture, six soil moisture regimes were tested, ranging from 0.16 to 1.00 gravimetric soil moisture (wt. of water/wt. of oven-dried organic soil). *M. anisopliae* was capable of causing mortality at all soil moistures tested with rate of mortality generally increasing with increasing soil moisture.

Inoculum density studies were conducted by amending fumigated soil with various conidial concentrations. Spore concentrations ranged from 0 to  $2 \times 10^4$  spores/gram of soil (oven-dried weight) in one experiment and from 0 to  $5 \times 10^4$  spores/gram of soil in the second experiment. Mortality was observed

at inoculum densities as low as 10 spores/gram of soil, with rate of mortality increasing with inoculum density.

These results demonstrate that *M. anisopliae* is capable of causing mortality at relatively low concentrations under environmental conditions well within the range of those occurring naturally in south Florida. Although encouraging in terms of potential for future biological control, further studies under simulated or actual field conditions will be necessary to properly evaluate control possibilities.

#### **A Laboratory Study on Flooding to Control the Wireworm *Melanotus communis* (Gyll.) (Coleoptera:Elateridae)**

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*Melanotus communis* wireworm collected from commercial sugarcane fields in Florida were subjected to various flooding regimes in a laboratory experiment. Wireworms drowned faster at 26° than at 18°C, from 13.5 to 38.2% (average = 24.3%) more wireworms died at 26° than at 18°C. Percent mortality of wireworms was consistently greater when wireworms were held in water than when they were in flooded soil, probably because minute pockets of air remained in flooded soil in spite of care taken to eliminate air. Based on width of pronotums as viewed dorsally, there was no significant difference in body size between wireworms that survived versus those that did not survive flooding (over all flooding regimes, with average pronotal width = 1.62 mm + .013s<sub>e</sub> and 1.65 mm + .022s<sub>e</sub> respectively). Continuous four-week floods killed significantly more wireworms than two successive two-week floods spaced one week apart when wireworms were held in water. In flooded soil, there was no significant difference in percent mortality of wireworms subjected to a four-week flood versus two successive two-week floods spaced one-week apart. Observed mortality percentages ranged from 1.8 percent (two-week flood in soil at 18°C) to 37.7 percent (two-week flood in water only at 26°C) to 66.7 percent (four-week flood in water only at 26°C)

#### **Soil Preference of Canegrubs (Coleoptera:Scarabaeidae) in Southern Queensland Sugarcane Fields**

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Thirty sugarcane fields located on different soil types in southern Queensland were sampled for the sugarcane grubs, *Antitrogon parvulus* Britton, *Lepidiota crinita* Brenske and *L. negatoria* Blackburn. Soil parameters (sand, silt, clay, Ph) were also, measured for each field. Correlations between the relative abundance of the grub species and soil parameters were determined. Distinct soil preferences were shown among the three grub species. *A. parvulus* was positively correlated with clay and silt and negatively correlated with sand. *L. crinita* showed no significant correlations with sand, silt or clay. *L. negatoria* was

positively correlated with sand and negatively correlated with clay and silt. None of the three species showed any significant correlation with soil Ph.

#### **Pubescence in Sugarcane as an Obstacle to Yellow Sugarcane Aphid Establishment**

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Pubescence does not occur on the leaf surface of commercial sugarcane varieties grown worldwide, most of which are hybrids of *Saccharum spp.* However, some clones of *Saccharum robustum* have pubescent leaves. Free-choice tests were conducted in the laboratory with yellow sugarcane aphids, *Sipha flava* (Forbes), which were placed in a cup holding excised leaves of *S. robustum* clones NG 77-147 (pubescent) and NG 77-195 (glabrous). In these tests, twice as many aphids preferred the smooth leaves

over the pubescent or hairy leaves, and these differences were statistically significant. The incorporation of pubescence into a commercial-type sugarcane variety could greatly reduce yellow sugarcane aphid infestations on sugarcane. This is the second sugarcane pest to which pubescence has been shown to have had an adverse effect. Previous tests concluded that pubescence on sugarcane leaves significantly reduced the rate of oviposition by the sugarcane borer.

#### **Incidence of Leaf Scald at the Sugarcane Field Station, Canal Point, Florida**

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J. L. Dean, University of Florida  
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In 1989, the incidence of leaf scald increased at the Canal Point Station over previous years. In stage II(88-series), over eight percent of the clones showed leaf scald (LSD) symptoms occurring from natural field infection at Canal Point. LSD to a lesser extent was also detected in other stages of the breeding program. Inoculated tests indicated a number of clones in the breeding program were susceptible to LSD. Of the Stage III (86-series and 84-series) clones, over 20 percent had an intermediate-to-susceptible reaction to LSD. The incidence of LSD infection in inoculated progeny of 12 families in Stage I(88-series), ranged from nine to 70 percent, indicating a high incidence in certain crosses.

#### **Use of an Enzyme Linked Immunosorbent Assay to Detect the Leaf Scald Pathogen, *Xanthomonas albilineans* in Sugarcane**

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A commercially-available monoclonal antibody specific to the genus *Xanthomonas* was used to develop an enzyme-linked immunosorbent assay (ELISA) to detect *Xanthomonas albilineans* in naturally-infected sugarcane stalks. In indirect ELISA assays, the monoclonal antibody reacted with pure cultures of *X. albilineans* and to extracts from symptomatic stalks, but not to extracts from healthy stalks or pure cultures of two other bacterial pathogens of sugarcane. When comparing the ELISA technique versus isolation in pure culture as detection procedures, *X. albilineans* was detected in 75.8 percent and 69.7 percent, respectively, of the extracts from leaf scald symptomatic stalks. In extracts prepared from asymptomatic stalks, *X. albilineans* was detected in 9.7 percent and 32.3 percent of the stalks with the ELISA and isolation procedures, respectively. Preliminary tests with ELISA amplification procedures show promise for increasing the sensitivity of the ELISA assay.

#### **Influence of Seedpiece Treatments and Seeding Density on Stalk Population and Yield of a Pineapple-Disease-Susceptible Sugarcane Cultivar**

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Pineapple disease, caused by the fungus *Ceratocystis paradoxa* may cause significant sugarcane stand reductions, particularly with certain cultivars Propiconazole (Tilt 3.6E) has proven efficacious in



controlling the disease, and recently received a Section 24C registration for use in Florida as a seedpiece dip. A field study was conducted to compare the efficacy of propiconazole dip application with in-furrow spray applications for controlling pineapple disease. The feasibility of planting a single line of fungicide-treated seedpieces rather than a double line of untreated seedpieces was also investigated.

Cultivar CP74-2005, a pineapple-disease-susceptible cultivar, was planted on January 7, 1989 in a 0.67 acre plot. A successively planted commercial sugarcane field was selected for the experimental site to ensure adequate disease pressure. The experiment consisted of a split-plot design with six replications. Main effects consisted of plantings containing single or double lines of cane seedpieces. Treatments consisted of an untreated check, a propiconazole dip treatment (25 ppm), and four propiconazole in-furrow applications at various rates and spray volumes. Overhead irrigation was applied subsequent to planting to provide the soil moisture necessary for adequate disease development.

Fungicide treatments resulted in significantly higher millable stalk populations, tons of cane per acre and sugar per acre than the untreated check, regardless of seedpiece density. In addition, the seedpiece dip treatment proved more efficacious than in-furrow spray applications at the rates and spray volumes tested. Interestingly, a single line of fungicide-dipped seedpieces provided for higher millable stalk populations and ultimately higher yield than a double line of untreated seedpieces. These preliminary results suggest that fungicide dip treatment of seedpieces may allow growers to reduce seeding rates, thereby increasing the amount of cane available for milling.

#### **Influence of Ethephon on Plant Population and Yield of Sugarcane**

R. W. Millhollon and B. L. Legendre  
Sugarcane Research Unit, Agricultural Research Service  
U.S. Department of Agriculture, Houma, Louisiana

Six field experiments, conducted over a four-year period and involving several commercial Louisiana sugarcane cultivars, were designed to evaluate the growth regulator ethephon [(2-chloroethyl phosphonic acid)] as a seed-piece dip and as early-season foliar treatment. For the dip, whole sugarcane stalks, less tops, were immersed for 30 minutes in a 250 ppm ethephon-water solution prior to planting. For the foliar treatment, ethephon at 0.28 kg/ha was sprayed over sugarcane in May when cane was approximately 61 cm high. Some treatments involved both the seed-piece dip and the foliar treatment. In three experiments, the standard planting rate (two stalks laid side-by-side in the furrow) was compared with a reduced planting rate (one stalk in the furrow). Both the ethephon dip and foliage treatments increased early-season shoot production and usually increased the number of mature stalks at harvest when compared to the controls. The dip treatment also increased yield of cane and sugar/ha by an average of eight percent at the reduced planting rate, but generally did not increase yields at the standard planting rate, apparently because of interplant competition. Yield increases occurred in the plant cane crop but not in the following first-ratoon crop. Foliage treatments, although increasing the number of mature stalks, did not increase yields of cane

and sugar/ha, apparently because of reduced stalk weight. Results indicate that ethephon treatments have potential for increasing yield of sugarcane and/or stalk populations where reduced planting rates are required.

#### **Predicting the Maturation of Selected Sugarcane Cultivars**

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Agricultural Research Service  
U. S. Department of Agriculture, Houma, Louisiana

Sugarcane (*Saccharum* interspecific hybrids) cultivars should be harvested according to their relative maturity during the scheduled harvest period to maximize sugar yields. Relative maturity can be expressed in terms of apparent sucrose (AS), apparent purity (AP) or yield of theoretically recoverable sugar per ton of cane (TRS/TC). An eight-year field study was conducted at Houma, Louisiana where AS, AP and TRS/TC were measured on eight commercial cultivars. Sugarcane juice, from stalk samples, was analyzed for these characteristics every two weeks beginning in September and ending in December. Mean stalk weight (MSW), which together with stalk number determines cane tonnage, was also obtained at each sampling date. The objectives of this study were: to plot changes over time in AS, AP, TRS/TC and MSW for each cultivar and



to determine the best trend (slope) to fit the data; to test the hypothesis that the slopes for each maturity component were similar among cultivars ( $P_1 = P_2 = P_3 \dots = P^k$ ); and to develop mathematical equations to describe the maturation of a cultivar based on AS, AP, or TRS/TC. An analysis of covariance with regressor variables and a test for heterogeneity showed that cultivars were significantly different ( $P = 0.05$ ) in their slopes for AS, AP, and TRS/TC. The rate of increase in MSW among cultivars did not vary significantly during the sampling period. Values for AS, AP and TRS/TC during the remainder of the harvest season were accurately predicted ( $R^2 = 0.97, 0.96$  and  $0.97$ , respectively) using the component maturity equations developed for each cultivar.

### **Post-Freeze Deterioration of Sugarcane Cultivars in Florida**

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University of Florida, Belle Glade, Florida

Modesto F. Ulloa, New Hope Sugar Cooperative  
Loxahatchee, Florida

The rate of sugarcane deterioration following exposure to freezing temperatures has been shown to be different among cultivars. Relative rates of post-freeze deterioration of most cultivars currently in commercial production have not been evaluated. The objective of this study was to compare the rates of deterioration of eight commercial sugarcane cultivars following 38 hours of sub-freezing temperatures occurring 24 December to 26 December 1989.

Stalk samples were randomly collected from plots of CP70-1133, CP72-1210, CP72-2086, CP75-1553, CP78-1247, with CP78-2114, CP80-1557, and CP80-1827 growing as first-ratoon cane in a randomized complete block experiment. Each plot was sampled on seven-day intervals from 26 December 1989 to 13 February 1990. Stalk weight, crusher juice Ph, titratable acidity, Brix, pol, and juice weight were measured. Theoretical sugar yield, percent juice sucrose, and juice purity were calculated. Sugar yield decreased for all cultivars from three through seven weeks post-freeze. The rate of decrease in sugar yield over the five-week period of deterioration was greatest for CP70-113, followed in order by CP80-1557, CP75-1553, CP72-2086, CP78-2114, CP78-1247, with CP80-1827 and CP72-1210 being approximately equal.

### **Effects of Freeze Damage on Sugarcane Juice Quality as affected by Cultivar and Location**

J. D. Miller, P.Y.P. Tai and M. Ulloa  
USDA-ARS Sugar Field Station, Canal Point, Florida

During the December 24, 1989 freeze, the temperature dropped below  $0^{\circ}\text{C}$  for more than 20 hours. Starting three days after the freeze, stalk samples of nine CP and two CL cultivars were taken weekly for nine weeks at three locations to measure the effect of the freeze on juice quality. Measures of juice quality included Brix, percent sucrose, percent purity, and sugar per metric ton of cane. Preliminary results indicated that in most cases the quality of freeze-damaged sugarcane declined gradually in a linear fashion.

Cultivars differed significantly within locations for rates of deterioration. Cultivars also differed in rates of deterioration among location indicating differences in intensity of the freeze. Cultivars with the lowest average weekly loss of sugar per ton (kg/t) were CP72-2086 (1.9), CP80-1827 (2.7), CP70-1527 (2.7), CP 72-1210 (3.0) and CL61-620 (3.6). While highest average losses were recorded in CP73-1547 (8.0), CP80-1743 (7.4) and CP70-1133 (7.3). When sugar/ton was used as the evaluation criterion averaged over locations and sampling dates, there were no significant differences among CP72-1210, CP72-2086, CP80-1827, CL61-620 and CP74-2005. Cultivars with the lowest average sugar per ton were CP70-1133 and CP73-1547. The probability of a freeze and its effects on varietal composition and harvesting schedules will be discussed.

## **Influence of Diluent Volume on Johnsongrass Control with Asulam**

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U. S. Department of Agriculture, Houma, Louisiana

Five field studies were conducted in second-ratoon crops of sugarcane cultivars, CP65-357 (1984 and 1985) and CP 72-370 (1986), heavily infested with rhizome johnsongrass, to test the effects of water volumes on the performance of asulam (Asulox). Asulam at 2.8 kg ai/ha was applied in water volumes of 47, 94, 190, 280, 370, and 560 L/ha postemergence over-the-top of johnsongrass and sugarcane as a 90-cm band in May of each year when johnsongrass stems were in the booting (flag leaf emerged) stage of development. The performance of the lower rate of asulam at the various water volumes was compared to a standard 3.7 kg/ha rate of asulam applied at 370 L/ha. Carrier(water) volumes were varied by adjusting sprayer speed (three studies) or nozzle size (two studies) to alter the number or size of the droplets, respectively.

Visual johnsongrass injury (chlorosis and necrosis) between various application volumes and between the 2.8 and 3.7 kg/ha rates of asulam was not significant four weeks after asulam treatment in any of the studies. Johnsongrass injury ranged from 55 to 70 percent with no sugarcane injury being observed. Where the number of droplets were altered little difference in johnsongrass recovery, based on panicle number in August or September, was observed between the use of the standard 3.7 kg/ha rate of asulam applied at 370 L/ha rate of asulam applied at 370 L/ha and asulam applied at 2.8 kg/ha in water volumes up to 370 L/ha. However, when asulam was applied at 2.8 kg/ha in a water volume of 560 L/ha, johnsongrass panicle numbers were double that of the standard treatment.

Significant differences in johnsongrass panicle production between the 2.8 kg/ha rate of asulam applied at the various water volumes and the standard rate of asulam were observed when the median droplet size was increased only in 1985. In 1985, johnsongrass panicle numbers were nearly three times higher following all treatments than in 1986. Under these conditions, the number of johnsongrass panicles was significantly higher than the standard asulam application when the 2.8 kg/ha rate of asulam was applied at the 560 and 47 L/ha water volumes. As an average of the five studies, johnsongrass panicle numbers following asulam application at 2.8 kg/ha were significantly less than the standard, 3.7 kg/ha rate, only when the 560 L/ha water volume was used. The increased johnsongrass recovery following the use of asulam in a water volume of 560 L/ha did not reduce net cane yields (tonnes), however.

Greenhouse studies were also conducted to see if surfactant usage affected the asulam response to water volume. Plants in the boot stage of development were thoroughly washed with water 24 hours after treatment with asulam at 2.8 kg/ha at water volumes of 47 to 370 L/ha  $\pm$  non-ionic surfactant at 0.5 percent v/v. After washing, johnsongrass control with asulam was higher when surfactant was included but not if the water volume was lowered, indicating that asulam absorption could be increased by the use of surfactant, but not by increasing the spray droplet's concentration of herbicide by reducing water volumes.

Results from field and greenhouse studies suggest that to ensure consistent performance with asulam, a carrier volume that is high enough to ensure coverage, but low enough to ensure droplet retention, should be selected and a surfactant included.

## **Itchgrass Competition and Control Systems in Sugarcane**

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Agricultural Research Service  
U. S. Department of Agriculture, Houma, Louisiana

Experiments were conducted near Houma, Louisiana from 1981 to 1989 to study the competitive effects of itchgrass (*Rottboellia cochinchinensis* (Lour.) Clayton) on yield of sugarcane. Itchgrass seed were planted in late February or early March along about 15 cm to the side of the line of sugarcane planted the previous autumn. Plants were thinned to one plant per 30 cm of row length after germination in March to simulate a moderately-heavy infestation. Itchgrass was removed by hand at monthly intervals from May to July and at harvest in November.



In two experiments with cultivar CP65-357, mean reduction in yield of cane/ha in the plant crops, as compared to a weed-free control, was zero, four, 11, and 22 percent for the May, June, July, and November removal dates, respectively. In one of the experiments, itchgrass-infested plots were also allowed to persist into the second crop (first ratoon) before being removed. Reduction in yield of cane/ha was zero, 10, 40 and 81 percent for the four removal dates, respectively. In another experiment with cultivar CP72-356, which is generally characterized as having a much heavier population of sugarcane tillers than CP65-357 both in the plant and first-ratoon crops, the yield reduction was zero, zero, four and seven percent in plant cane and two, nine, 18 and 18 percent in the first ratoon for the four harvest dates, respectively.

#### **Comparisons of Pre-emergence Herbicides for Itchgrass Control and Sugarcane Injury**

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Louisiana State University Agricultural Center  
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Itchgrass (*Rottboellia cochinchinensis*) control and sugarcane (*Saccharum* sp) injury with pre-emergence herbicides pendimethalin (trade name Prowl), prodiamine, clomazone (trade name Command), fomesafen (trade name Reflex), quinchlorac, teracil (trade name Sinbar), metribuzin (trade name Sencor/Lexone), and atrazine were compared in 1989 at Loreauville and Labadieville, Louisiana. Pendimethalin at 2.2 and 3.4 kg/ha plus atrazine, prodiamine at 1.7 to 2.8 kg/ha, clomazone at 1.1 to 2.2 kg/ha, and fomesafen at 0.8 and 1.1 kg/ha provided 80 percent or more early-season itchgrass control at both locations. Itchgrass populations late-season for those treatments were reduced at least 79 percent and 48 percent when compared to the untreated check at Loreauville and Labadieville, respectively. Sugarcane injury was minimal for all treatments but some temporary whitening of plants was observed with clomazone.

Sugarcane stalk heights were similar regardless of herbicide treatment. Stalk populations following quinchlorac, terbacil, metribuzin, and atrazine were similar to be untreated check, reflective of poor early-season itchgrass control. Sugar yields at Loreauville with pendimethalin at 2.2 kg/ha plus atrazine,

prodiamine at 2.8 kg/ha, clomazone at all rates, fomesafen at 1.1 kg/ha, and metribuzin at 2.6 kg/ha were significantly greater than the untreated check.

#### **Management Practices of a Sugarcane-Sweet Corn Rotation System In Florida**

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Canal Point Florida

Modesto F. Ulloa, Agronomist, New Hope Sugar Cooperative  
Pahokee, Florida

A popular crop rotation system among Florida sugarcane growers is to grow sweet corn while their sugarcane land is fallow. One incompatible feature of this farming system is the potential for mismanagement of fertilizers. Residuals of phosphorous and potassium fertilizers applied to sweet corn may be detrimental to sugarcane. One objective of this study was to determine for four cultivars of sugarcane if standard sweet corn fertilizer residues were in fact detrimental to sugarcane yields. An equally-important objective was to determine fertilizer requirements of a two-crop cycle (plant cane through first ratoon) of sugarcane planted after a spring sweet corn crop. An experiment with four fertilizer treatments was conducted at three locations with different soil characteristics. The four treatments were: sugarcane after corn with no phosphorous or potassium fertilizer applied to the sugarcane; sugarcane after corn with potassium fertilizer applied to the sugarcane; sugarcane grown after a dry fallow period with only potassium applied to the sugarcane; and sugarcane grown after a dry fallow period with phosphorous and potassium applied to the sugarcane. On average, sugar concentration of sugarcane grown after corn was significantly less than that of sugarcane planted after a dry fallow period. Yields of cane were highest for sugarcane grown after corn and fertilized with potassium. Sugar-per-acre yields were similar for all treatments averaged

across all locations. However, there were important fertilizer and location interactions as well as fertilizer by crop year interactions. Thus, on the average, planting, fertilizing, and harvesting sweet corn before planting sugarcane was not detrimental to sugarcane yields. However, there were locations and crop years that were better suited to the rotation than others. There were no important variety interactions with fertilizer treatments. We concluded that the sugarcane-sweet corn rotation can be successful if appropriate management practices are used at each location.

#### **Association of Sugarcane Leaf Nutrient Status with Sugarcane Rust Severity**

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L. J. Henderson, M. S. Irey  
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Sugarcane rust (*Puccinia melanoccephala*) was first detected in Florida during 1979. Recent studies have shown that the severity of rust in Florida is related to variability of soil Ph and to the plant nutrient status. The object of these studies was to quantify the influence of plant nutrition on rust severity. In studies conducted at five sites on organic and mineral soils, rust severity ratings and nutrient analysis of infected leaves were determined. Rust severity was spatially variable across each site and ratings and leaf samples were taken across x-y coordinates. Across all sites, low and high leaf N content was associated with low rust severity. Although leaf Mn also appeared to be associated with rust severity, Mn was also high correlated to soil Ph.

#### **Benefits of Subsurface Draining Land for Sugarcane**

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Baton Rouge, Louisiana

R. L. Bengtson  
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In the 1970s, a water table depth experiment with 40m<sup>2</sup> plots in Baton Rouge, Louisiana showed that average sugarcane yield and stand longevity from a 120 cm water table depth was greater than from 60 cm water table depth. Since this experiment was on small plots, a four-hectare field experiment was conducted in St. James, Louisiana during 1977-1980, 1982-1985, and 1987-1989 to determine the feasibility and crop response to maintaining a deep water table in a large field.

Yield and stand longevity trends shown in the small-plot experiment were also indicated in the large field study, although yields were less in the large project. During the 11-year study, average plant cane yields were 77.4 t/ha and 73.4 t/ha in fields with and without subsurface drainage, respectively; average third ratoon yields were 66.8 t/ha and 53.7 t/ha, respectively. Normally only two ratoon crops are grown in Louisiana. Yields declined at a rate of 3.6 and 7.8 t/ha/yr in the drained and nondrained field, respectively. Trends in sugar yields were similar.

Another benefit of subsurface drainage is that one can enter a drained field with machinery for field work two or three days earlier than a nondrained field during spring and summer months. Subsurface drainage also increases land available for sugarcane production by about five percent because the number of surface drainage land is less than for land not subsurface drained.



## **MANUFACTURING ABSTRACTS**

### **Starch Concentration of Maturing Sugarcane**

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In relation to other non-sugars dissolved in sugarcane juice, starch has a greater tendency to be included in raw sugar crystals during sugar boiling, and hence gets preferentially transferred to the refinery. Starch affects viscosity, filterability, and crystal yield; starch increases sugar loss in molasses. Interest has increased in recent years in the U.S. because starch occurs at high concentration in raw sugar produced in Louisiana and other U. S. areas. Starch is seldom considered an important character during breeding and selecting of new sugarcane varieties, but it is important to raw sugar factories and refineries because it adversely affects processing and the quality of sugar produced.

Starch concentration of eight commercial varieties, CP 65-357, CP 70-321, CP 72-356, CP 72-370, CP 74-383, CP 76-331, CP 79-318 and NCo 310 was monitored during the 1989 harvest season in Louisiana. Sampling began in mid-September and continued every two weeks through the first week in December using conventional milling. Other juice characteristics measured included Brix, sucrose, purity, total polysaccharides, and dextran. The results generally showed that CP 72-370 was highest in starch concentration and CP 70-321 was lowest. No associations were found between starch concentration and Brix, sucrose, and purity. These data and correlations between starch and other juice characters will be presented and discussed.

### **Getting the most Horsepower to the Cane**

Robert P. Harper, Industrial Machinery Systems, Inc.  
New Orleans, Louisiana

The object of each and every mill is to maximize their return on investment. In a micro sense there are time, money, materials, and equipment used to develop horsepower for grinding cane. The efficiency with which this horsepower can be delivered to the cane itself is directly proportional to return on investment as experienced through greater extraction.

This paper will discuss how to maximize the amount of horsepower through a grinding mill gear train and key factors in their design.

The following areas will be discussed:

- Fixed and variable costs of developing horsepower through steam;
- the relationship of horsepower versus grinding rates and extraction;
- principles of involute gear form and how they transmit power;
- value comparisons on capital expenditures for gear trains versus grinding rates in terms of extraction; and
- design considerations of mill gearing support systems such as bearing, housing, and lubrication systems.

### **A Comparison Between a Conventional and a Press-Roller Mill Tandem**

A. Arvesu, Sugarcane Growers Cooperative  
Belle Glade, Florida

For the 1989-90 Crop Season, Sugar Cane Growers Cooperative of Florida modified five of the six mill on one of their two tandems from conventional to press-roller mills. Since the Cooperative has two practically identical tandems, a comparison between results in each tandem, in the same crop, gives a good

and fair evaluation. When comparing different crops many other factors may affect the results. In this paper a comparison of the results is presented and improvements obtained with the conversion are described.

#### **The Fourth Roller Mills at Okeelanta Corporation Preliminary Results**

Roger King, Frank Fernandez, and Luis Perera  
Okeelanta Corporation, South Bay, Florida

Fourth rollers (press rollers) are being progressively installed in all the mills of Okeelanta's two tandems. The factory is in the second year of the three-year program. Preliminary results on milling efficiency and experience gained to the present time will be reviewed.

#### **Ultrafiltration as an Alternative to Chemical Clarification in Cane Juice Polarization Analyses**

R. P. DeStefano, Edgar Aguirre, and Hector Llorens  
United State Sugar Corporation, Clewiston, Florida

A commercially-available patented ultra-filtration device has been exhaustively tested in two Florida raw sugar mills and found to yield clear juice samples suitable for direct polarizations analysis without the use of chemical clarification. Based on over 1,000 comparisons, polarization results from the ultrafiltered juices as very strongly correlated with polarization results from the same juices clarified with lead subacetate or with a combination of lime and aluminum chloride. The equipment is rugged, simple to maintain, and easily operated by regular-juice chemists.

#### **Sugar Cane Factory Solid and Liquid Waste Streams**

Stephen J. Clarke, Audubon Sugar Institute  
Louisiana Agricultural Experiment Station  
Baton Rouge, Louisiana

Current federal and state regulations, and the need to be good corporate citizens, require that sugar cane factories control their discharges into the environment. The areas of interest for this discussion are water streams leaving the factories, both the material in solution (principally sugar) and suspended solids from cane wash systems and slurried filter cake and fly ash. High BOD is associated with many of the streams, and about one-half of the total BOD exiting the factory is from the slurried filter cake.

Measurements made at several Louisiana factories during the 1989 season showed considerable variation, by a factor of 10 in some cases, in the sugar levels in the streams exiting the factory. Major causes of the variation are the water flow systems within the factory and in the cane washing systems. A mill with limited evaporator capacity showed high sugar levels in the condenser water and this water was used as make-up for the cane washing system. The goals of this work are to minimize sugar loss and to simplify effluent handling. An example of the latter would be a combined filtration of the filter cake and fly ash slurries to return the sugar to process, producing a dry, solid residue suitable for use in the fields. The data from the 1989 season and various options for effluent control will be discussed.

#### **Applications and Benefits of Surfactants in the Low Grade Masseccutes**

Roberto A. Echemendia, Delta Chemical and Services, Inc.  
Coral Gables, Florida

Based on the mechanism of action and statistical analysis, three different ways to use surfactants during the low grade boiling are compared. It is concluded that the three-strike methods offered the best benefits. It is also shown that products commonly used in critical situations can also be highly helpful under normal conditions. Advantages include: increases in capacity of above 20 percent; increased productivity,

i.e., processing the same amount of material in a shorter time, thereby saving labor, operating, and maintenance costs; and allowing larger amounts of cane to be processed in a fixed period of time. Benefits in sugar recovery and the conservation of energy are also discussed.

#### **Dextran Model for Predicting Dextran in Sugars or a Two and One-Half Strike Boiling System**

Jose F. Alvarez, Sugar Cane Growers Cooperative of Florida  
Belle Glade, Florida

The correlation between the level of dextran in clarified juice and the level of dextran in sugar is not an obvious one. In order to understand and define this correlation, a model was developed to simulate the movement of dextran in the boiling house and to predict the dextran in sugar from the dextran in clarified juice. Although the model predicts within 90 percent, it does yield some insights into the movement of dextran inside a boiling house.

#### **Quintuple-Effect Evaporation at Glades Sugar House**

Tirso M. Carreja, Sugar Cane Growers Cooperative of Florida  
Belle Glade, Florida

The change from quadruple-effect evaporation with vapor bleeding from the first body to quintuple-effect evaporation with vapor bleeding from the first and second bodies at the evaporation station at Glades Sugar House created a large economy in factory steam consumption. This presentation shows estimated evaporation steam balance under both conditions. In addition, it provides a brief description of the juice and steam flow meters that were installed to help find the most efficient operation at the evaporation station. These flow meters were installed and used during the past crop season. Heat balance from last crop season, based on information collected from these flow meters and from existing conditions in the plant, is also presented. Finally, advice is given on the operation of this quintuple-effect arrangement.

#### **Automatic Problem Reporting of Batch Centrifugals**

Dennis H. Sellers, Sugar Cane Growers Cooperative of Florida,  
Belle Glade, Florida

This paper explains how Sugar Cane Growers Cooperative of Florida was able to automatically determine batch centrifugal problems and report them to the centrifugal operators. The difficulty of determining problems on batch centrifugals was overcome with the use of programmable controllers. This reduced the troubleshooting time of over 40 common problems on the centrifugals from hours or days to just minutes.

#### **Sugar Station/Audubon Sugar Institute - Past, Present, Future**

F. A. Martin, Sugar Station/Audubon Sugar Institute  
Louisiana Agricultural Experiment Station  
Baton Rouge, Louisiana

The Sugar Experiment Station and the Audubon Sugar School were created in 1885 and 1891 respectively, to address the needs of the Louisiana sugarcane industry. Dr. W. C. Stubbs, Director stated the objectives as:

- To learn to grow more cane with more sugar per given area;
- to study the economics of the sugar industry;
- to study the scientific and practical methods of making sugar; and
- to supply information to the subscriber of the station and to advance the sugar interest of Louisiana.

Although the Audubon Sugar school was intended for graduates of technical courses, by 1899 the



program was extended to cover five years of study, leading to a B.S. degree. During the fourth and fifth years, students received practical instruction in sugar technology at the sugar house in Audubon Park. Audubon Sugar School graduates in agriculture, chemistry, and engineering were sought after by cane sugar industries throughout the world.

In 1925 when the University was moved to its present location, the Sugar Experiment Station and sugarcane production research remained in the Louisiana Agricultural Experiment Station. The Audubon Sugar Factory was situated in the Chemical Engineering Department. For many years the Audubon Sugar Factory processed the sugarcane produced on university land. Because of financial considerations, and the fact that the LSU campus grew around the Audubon Sugar Factory, routine grinding of sugarcane was discontinued in the mid-1960s. The Audubon Sugar Factory would only be run for research projects.

In 1976, the Audubon Sugar Factory was transformed into the Audubon Sugar Institute. From 1977 through 1985 the position of the ASI in the LSU system was unsettled. Just as a critical mass of faculty and staff was being approached, the budget cuts of the mid-1980s took heavy tolls on the ASI budget. The Audubon Sugar Institute was transferred to the Louisiana Agricultural Experiment Station in 1987. In September 1988, ASI and the Sugar Station were reunited as a single budgetary unit in the Louisiana Agricultural Experiment Station.

After reviewing the expectations of the Louisiana sugarcane industry and the report of the special CSRS review team, it is apparent that the objectives stated by Dr. Stubbs and the training objectives of the Audubon Sugar School are still valid. It is our intention to ensure that relevant and needed production and processing research and service activities will be conducted in the Louisiana Agricultural Experiment Station. We will work with appropriate degree-granting units to ensure the availability of college graduates with knowledge of sugar technologies.



## AMERICAN SOCIETY OF SUGAR CANE TECHNOLOGISTS

### EDITORIAL POLICY

#### Nature of papers to be published:

Papers submitted must represent a significant technological or scientific contribution. Papers will be limited to the production and processing of sugarcane, or to subjects logically related. Authors may submit papers that represent a review, a new approach to field or factory problems, or new knowledge gained through experimentation. Papers promoting machinery or commercial products will not be acceptable.

#### Frequency of publication:

The Journal will appear at least once a year. At the direction of the Joint Executive Committee, the Journal may appear more frequently. Contributed papers not presented at a meeting may be reviewed, edited, and published if the editorial criteria are met.

#### Editorial Committee:

The Editorial Committee shall be composed of the managing editor, technical editor for the Agricultural Section and technical editor for the Processing Section.

The Editorial Committee shall regulate the Journal content and assure its quality. They are charged with the authority necessary to achieve these goals. The Editorial Committee shall determine broad policy. Each editor will serve for three years; he may at the Joint Executive Committee's discretion, serve beyond the expiration of his term.

#### Handling of manuscripts:

Four copies of each manuscript are submitted to the managing editor. Manuscripts received by the managing editor will be assigned a registration number determined serially by the date of receipt. The managing editor writes to the one who submitted the paper to inform the author of the receipt of the paper, the registration number which must be used in all correspondence regarding it, and the page cost of publishing.

The technical editor receives from the managing editor all papers whose subject matter falls in his "area." He obtains at least two reviews for each paper from qualified persons. The identities of reviewers must not be revealed to each other nor to the author during the review process. Instructions sent with the papers emphasize the necessity for promptness as well as thoroughness in making the review. Page charges will be assessed for the entire manuscript for non-members. Members will be assessed for those pages in excess of ten (10) double spaced pica typed pages of 8 1/2" x 11" dimension with one (1) inch margins.

When a paper is returned by a reviewer, the technical editor evaluates the paper and the recommendations of the reviewers. If the paper as received is recommended by two reviewers for publication in the Journal, it is sent to the managing editor.

If major revisions are recommended, the technical editor sends the paper to the author for this purpose, along with anonymous copies of reviewers' recommendations. When the paper is returned to the technical editor, he will judge the adequacy of the revision and should send the paper back to any reviewer who requested major changes, for his further review. When the paper has been revised satisfactorily, it is sent to the managing editor for publishing. A paper sent to its author for revision and held more than 6 months will be given a new date of receipt when returned. This date will determine the priority of publication of the paper.

A paper rejected by one reviewer may be sent to additional reviewers until two reviewers either accept or reject the paper.

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Format Example

EVALUATION OF SUGARCANE CHARACTERISTICS  
FOR MECHANICAL HARVESTING IN FLORIDA

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Agricultural Engineers, SEA, USDA, Belle Glade, Florida

J. D. Miller and P. Tai  
Research Geneticists, SEA, USDA, and Canal Point, Florida

ABSTRACT

INTRODUCTION

MATERIALS AND METHODS

RESULTS

Table 1. Varietal characteristics of nine varieties of sugarcane over three-year period at Belle Glade, Florida.

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Figure 1. Relative size of membrane pores.

DISCUSSION

CONCLUSIONS

ACKNOWLEDGMENTS

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